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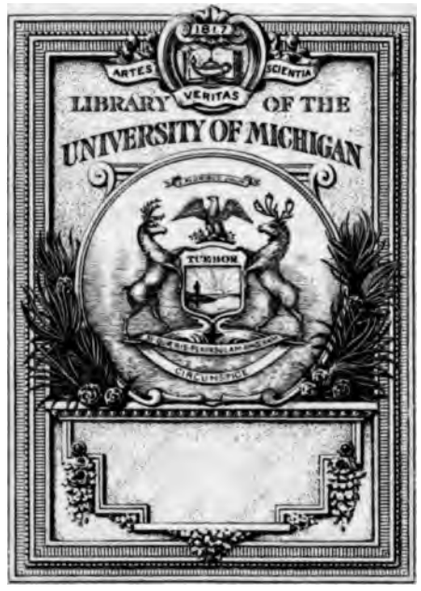
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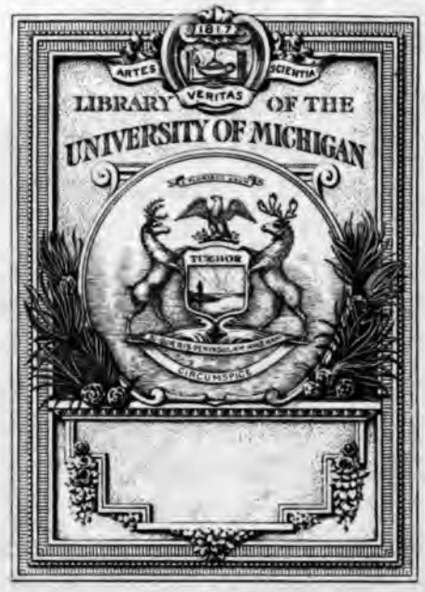
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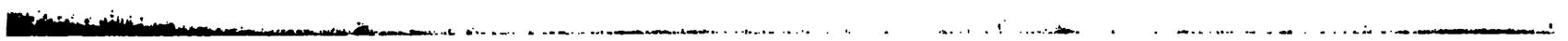

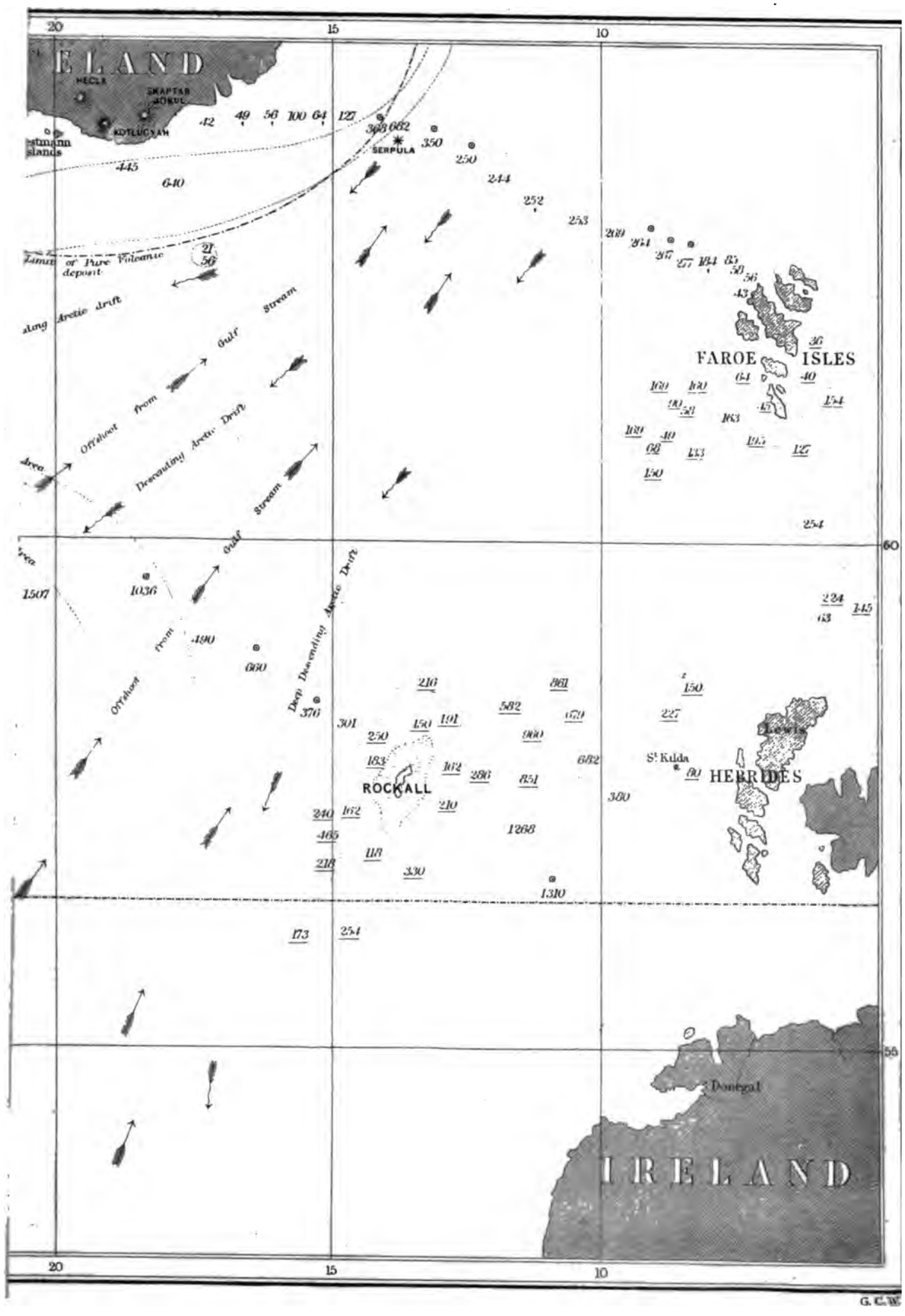
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THE

NORTH-ATLANTIC SEA-BED:

COMPRISING

A DIARY OF THE VOYAGE ON BOARD H.M.S. BULLDOG, IN 1860;

AND

OBSERVATIONS ON THE PRESENCE OF ANIMAL LIFE, AND THE FORMATION AND NATURE OF ORGANIC DEPOSITS, AT GREAT DEPTHS IN THE OCEAN.

BY

George Charles

G. C. WALLICH, M.D., F.L.S., F.G.S.,

SURGEON ON THE RETIRED LIST H.M. INDIAN ARMY; NATURALIST TO THE EXPEDITION DESPATCHED IN THE ABOVE YEAR, UNDER COMMAND OF SIR F. L. M'CLINTOCK, R.N., TO SURVEY THE PROPOSED NORTH-ATLANTIC TELEGRAPH ROUTE BETWEEN GREAT BRITAIN AND AMERICA.

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TO

HIS GRACE THE DUKE OF SOMERSET, K.G.,

FIRST LORD COMMISSIONER FOR EXECUTING THE OFFICE OF LORD HIGH ADMIRAL OF GREAT BRITAIN AND IRELAND,

THIS VOLUME,

EMBODYING A SMALL CONTRIBUTION TO THE NATURAL HISTORY OF THE SEA,

IS,

BY PERMISSION,

MOST RESPECTFULLY AND GRATEFULLY

DEDICATED

BY

THE AUTHOR.

THE

NORTH-ATLANTIC SEA-BED.

PART I.

CHAPTER I.

DEPARTURE FROM STORNOWAY.—THE FARÖE ISLANDS.—SUSPIRIA DE PROFUNDIS.—BASALTIC DRIFT.—EFFECTS OF DEEP-SEATED CURRENTS.—VOLCANIC DETRITUS ALONG SEA-BED.—DEEP ARCTIC CURRENT.—THE WESTMANN ISLANDS.—ASPECT OF SOUTHERN ICELAND.—CHARACTER OF THE SEA-BED ALONG ITS SHORE.—ARRIVAL AT REKIAVIK.—ICELANDIC SCENERY.—GREAT LAVA-STREAMS.—ABRASIVE NATURE OF THE SCORIACEOUS ROCK.—OBSIDIAN DUST.—MODIFICATION OF SIR JOHN ROSS'S SOUNDING "CLAMS."—EFFECTS OF RECENT ERUPTION OF KOTLA.—EJECTION OF ICE FROM CRATER.—EXPLANATION OF THIS PHENOMENON.—PREVALENCE OF SICKNESS DURING VOLCANIC ERUPTIONS.

ON the 2nd of July, 1860, H.M.S. Bulldog steamed out of the little harbour of Stornoway, and our North-Atlantic cruise fairly commenced.

July 4.—For the first time since leaving Spithead, now eleven days ago, the sun has shone out brightly, and we are revelling in a glorious summer morning. About an hour after midnight the "Dimon Rocks" were sighted, although distant between thirty and thirty-five miles; so that we are already in the region of no night.

Nothing could exceed the beauty of the panorama presented to our view, as, one after another, the bold headlands of the Faröe Islands burst upon us. Although no vestige of tree or shrub clothes the declivities, and the sombre tints of the trap rock are relieved only here and there by brilliant patches of green-sward, or orange-tinted lichens, so varied is the outline, and intersected with

chasms and sparkling water-courses, that all idea of monotony is lost in the general grandeur of the scenery.

Suddenly the magnificent fiord which separates Stromöe and Naalsäe, the two principal islands of the group, from each other, opened out upon us. Sweeping round a bold headland into this, we at once found ourselves surrounded by lofty hills, whose bases, broken up into every variety of cliff and cavern, formed the water-line, whilst their summits might be seen, far in the background, stretching beyond an alternating series of ridges and chasms, until they attained the height of from 1500 to 2000 feet.

In some of the more elevated hollows large drifts of dazzling snow still lingered, and gave token of a late and boisterous winter. Strange to say, these drifts were principally observable on the southern slopes.

But the most charming feature was the constant succession of torrents and cascades which dashed impetuously downwards to the fiords, and looked in the distance like so many living streams of alabaster; whilst around the summits of the ranges whence they sprung the layers of grey mist hung for a moment or two, as if clasping them in a parting embrace, and then glided away, or became dissipated in the atmosphere around.

Continuing our course along the fiords, which were rarely less than from one to two miles across, we speedily reached Thorshaven, the chief town of the Faröe Islands, took on board a pilot, and finally came to anchor, about noon, at the entrance to the little land-locked bay of Westmannshaven.

Having hired a boat, and satisfied my curiosity by a ramble ashore, I devoted the remainder of the afternoon to dredging.

July 6.—Too foggy yesterday to leave the anchorage and get to sea again. Towards evening the rain, which came down in torrents during the afternoon, cleared off. I sat up till midnight, and at that hour took a sketch of the village and harbour. The pink tints left by the setting sun were still visible on some clouds that floated away behind the western range of hills, and it seemed almost impossible to believe that night was so far advanced.

Up anchor and away at 7 A.M. The morning gave promise of fine weather; but it soon became foggy again, and we were accordingly doomed to lose all save a partial glimpse of the famed promontory of "Mühlen Head." But even this glimpse afforded an idea of its grandeur; for, steering along almost within

stone's-throw of the shore, we could discern its perpendicular character, and the mighty blocks of detached cliff standing out from the main mass like outworks to some Titanic fortress. In ten minutes after catching our parting view of this towering headland, we were running along merrily with a clear blue sky overhead and sunshine; so that the demon of the Faröese mist only remained faithful to his own traditions.

Several soundings have been taken today; but these are of no interest, being from shoal water. Although it is blowing fresh from N.W. almost directly in our teeth, the last cast was "up and down"—showing how admirably a fixed position may be maintained under steam, even in bad weather. Another sounding is going on whilst I write. It is midnight, and yet the light streams down through my cabin windows.

July 9.—The weather, which has been bad enough for the past two days, threatens to become still worse. This is provoking; for under more favourable circumstances we should, ere this time, have sighted the coast of Iceland, somewhere in the vicinity of Ingolfshofde, and been near enough to the land to see Hecla and the new volcano which burst into activity in May last. As it is, the ship has been kept well clear of the land, and we shall, in all probability, lose a very grand spectacle.

From five to six soundings have been taken daily, the intervals varying from a few miles, in the neighbourhood of the coast-lines, to a degree, or thereabouts, at mid-distance between them. In the examination of the material brought up, my time has been so fully occupied, that anything like a few hours' continuous rest is out of the question.

Already my views, regarding the extension of animal life to much greater depths than is usually allowed, have received a certain degree of confirmation. In a sounding (No. 15) taken yesterday, at a point about two-thirds of the distance between the Faröes and Iceland, the Conical Cup* brought up, from a depth of 682 fathoms, a piece of quartz-rock about an inch square, several fragments of basalt, an old and much-worn fragmentary valve of *Pollicipes*, a minute pellet of mud about the size of a pea, a calcareous *Serpula*-tube—about

* For a description of this and other forms of Sounding apparatus alluded to in the Diary, the reader is referred to the Chapter on Sounding and Sounding Apparatus. The organisms referred to will be found described in the Chapters devoted to Natural History.

remarkable fact that, throughout the entire distance, nearly 200 miles, between the point at which this sounding was taken and the Faröes, not the slightest trace of volcanic detritus appears in the material brought up from the bottom. Between long. 7° 55′ and 13° 45′ inclusive, eleven casts were made, and bottom brought up five times; so that, had volcanic particles been present, some trace of them must at all events have been observable. This becomes the more remarkable when it is borne in mind that, during eruptions of Hecla and Skaptar Jokul, the volcanic particles have been borne across the whole breadth of the North Sea, to the coast of Norway, in nearly the same parallel of latitude as the Faröes. It is difficult, therefore, to conceive that this large area of sea-bed, or at any rate that portion of it constituting the middle third of the distance alluded to, should not have received a share of the deposit, under favourable conditions as to atmospheric currents.

On the other hand, from the 682-fathom locality to our present position, which I should say is not more than forty miles from the southern shore of Iceland, out of eight casts, seven on being brought up have each presented volcanic detritus.

Combining all these facts together, I am clearly of opinion that a deep-seated drift, bringing the colder waters from Spitzbergen and the western side of Nova Zembla, sets along this middle tract and bears away with it the volcanic debris. We know that the Arctic drift splits up into two branches, as it were, on coming across the northern shores of Spitzbergen: one branch, passing down to the south-westward and carrying along with it the mass of ice which hugs the eastern coast of Greenland, doubles Cape Farewell, and then streams up along the western shores of Greenland,—the other branch being traceable for several degrees to the southward and eastward of Spitzbergen, and then gradually lost in the fork of the Gulf Stream, the western arm of which ascends in a due northerly direction, so as to impinge against the southern portion of Spitzbergen, whilst the other arm, turning aside at nearly a right angle, assumes an easterly course. That branch of the descending or Arctic drift which is traceable into the bifurcation of the ascending or Gulf Stream must find its way somehow to the Equator; and, as a natural consequence, it follows the recognized practice of all cold currents when brought into contact with warmer ones, and thus travels below it to its destination. Continued in its original course, this current would traverse

the middle space between the Faröes and Iceland; and, as has been shown, if moving at no greater velocity than 600 yards (that is, about one-third of a mile) per hour, or half the speed at which we know the western superficial branch moves round Cape Farewell, it would be quite powerful enough, independently of the decrease in the specific gravity of particles of mineral matter owing to the conditions already discussed, to bear along those particles and thus to remove all trace of debris other than that reproduced by its own action. By means of this current, the volcanic particles which, according to Captain Maury, strew the bed of the Mid-Atlantic, between the parallels of 47° and 52°, along no less than twenty-five degrees of longitude, are borne down from the Icelandic coasts. In the "Notes"* published by me immediately after my return from the cruise, I adverted to this as being the true source of the volcanic matters present in the latitudes referred to, and thus corroborated the shrewd suggestion of the late Professor Bailey.

I think we are therefore warranted in assuming that a current having a moderate velocity, such as that referred to as being sufficient to account for the phenomena in question, does exist, and that it flows away in a south-westerly course, under the warmer waters of the ascending Gulf Stream, and gradually mingles with the general gathering of the polar waters around the Equator,—an additional proof of the correctness of this view being derived from the fact, fully borne out by various navigators, that about the 63rd parallel of latitude the temperatures of the surface-water and that at a hundred fathoms' depth do not usually differ by more than three degrees—clearly indicating that, at one-sixth of the greatest recorded depth of water, the temperature of the Gulf Stream has not yet been materially diminished, and, inversely, that the cold drift is still too deep-seated to have been in operation at that distance from the surface.

July 10.—Strong head winds, cold drizzling fogs, or drenching rain, with a nasty chopping sea, have haunted us ever since we drew near to "The Inferno." Our course has been close to the northward of the Westmann Islands, a group of purely volcanic origin, and abounding in magnificently bold scenery. Most of the islands consist of trappean rock thrust up sheer from the sea to a height of several hundred feet. In one place the entire face of one of these huge masses has been rifted off and hurled forwards as it were, its angle of inclination being

* "Notes on the Presence of Animal Life at vast Depths in the Sea."

so great as to give it the appearance of being about to crash headlong into the waters beneath. In a second mass of nearly similar dimensions one half has become partially submerged, whilst the other defiantly stretches forth its rugged and perpendicular front to the waves that lash themselves into a frenzy in their effort to make it yield also. On the land side, the mountain-chains, whenever it was possible to snatch a momentary glimpse of them by the uplifting of the clouds, presented a most weird appearance, and told of the terrific forces which were in operation at their upheaval. But Hecla, Eyefialla, Kotlugia, and Skaptar Jokul remained provokingly hidden from view; and after straining my eyes for several hours, and vainly endeavouring to deceive myself into the belief that every towering cone whose summit was swathed in mist must be belching forth its sulphurous torrent, I was at last glad to beat a retreat, and go to my "Plutonic tallies" (as Captain Maury calls them) obtained from the regions below.

Whilst the increase in depth of water, from the north-west angle of the Faröes, was singularly gradual and regular till we reached the vicinity of the 682-fathom point, from thence to the south-westerly part of Iceland the evidence of a more recent igneous-rock formation at once discloses itself in a series of alternating elevations and depressions. Thus, at a distance of about forty miles to the westward we find 64 fathoms; then a plateau of nearly seventy miles diameter, on which the depth varies between 40 and 100 fathoms; and lastly, another dip of 640 fathoms, which decreases to 445 fathoms at fifteen miles distance from the Icelandic coast.

Now these alternations of level are by no means great; and, so far as the soundings show, there is no reason whatever why a telegraphic cable should not sink down into the position destined for it, even if run transversely across all these ridges and hollows. But this is only on the supposition that the depths indicated are really the greatest that exist, and that, along the intervals, other depressions and elevations, more or less sudden as the case may be, do not occur. If one can judge from the character of the islands we have passed today, namely the Westmanns, and from that of the mainland, so far as the mists have allowed us to catch a glimpse of it, it would seem highly probable that the alternations are infinitely more frequent, and consequently that a survey of a sufficiently comprehensive kind to indicate the direction and extent of the valley-lines is absolutely indispensable, if a cable is to be submerged in this direction

with the slightest prospect of safety. Wherever the submarine valleys happen to be narrow and irregular, no matter how slowly a cable may be paid out, festoons would form, the weight of which, acting on the points of contact, would inevitably engender a fatal strain. Whether the strata at the bottom be of the more recent or ancient igneous character, the danger of abrasive action would exist in an equal degree so long as the ridges supported the layer of emery-like deposit which prevails along the southern coast-line of the island; and, as already stated, the only mode of counteracting this danger is to deposit a cable, not across the endless series of sharp ridges, but along the most suitable of the valleys protected by them.

July 12.—Rekiavik. After rounding Rekianess the evening before last, in a stiff gale from the southward, and having seen quite as much as was desirable of the reef-bound coast that stretches for some distance to the east of that Cape, we dropped anchor yesterday morning at Rekiavik. Whether owing to the still gloomy state of the weather, or a certain demure look inherent in the place, the first feeling engendered, on taking a survey of it from our anchorage, was one of unmingled disappointment. Instead of a picturesque town nestling, like a sea-bird, at the base of vast broken cliffs such as one might expect to come across in an intensely volcanic region, a range of straggling wooden houses extending along a low, somewhat broken slope, on which no trace of verdure was observable, with a murky background of mist solid enough to have concealed Paradise, was all that met our gaze. The peculiar summer (of 1860) had evidently "set in with its accustomed severity" in these, as in our own lower latitudes; and it was not until a late hour in the evening that the sky cleared, and revealed the glorious amphitheatre by which Faxe fiord is surrounded. During a few moments of sunshine, the effect was almost magical,—the distant snow-capped ranges of mountain, which shut out the horizon to the north-westward, being brought forward with a distinctness not only of outline but of detail, that would have made them appear close to the eye, but for the multitude of intermediate peaks which glistened as if suddenly transformed into a tempest of adamant; whilst some sixty miles distant to the north-westward might be seen the gigantic cone of Snæfells, towering up from the sea in isolated grandeur.

There is something singularly impressive in the knowledge that we are standing on the threshold of the mightiest convulsions the surface of our planet

has witnessed. Although fully alive to the fact that, throughout the globe, a mere crust intervenes between us and the vestiges of similar phenomena, it is not until our feet press the blistered lava-bed, and we actually see around us the vast blocks which once fell thundering into the positions they still occupy, that the mind wakes to a conception of the sublimity and grandeur of such a scene.

The whole of the south-western peninsula of Iceland presents the appearance of having been poured forth as a vast continuous lava-stream. Along the eastern boundary of this tract may be seen a number of well-defined cones, which constitute the flank company of a series extending diagonally across to the north-eastern extremity of the island. Those in the neighbourhood of Rekiavik, and stretching in a south-westerly direction down towards Rekianess, would seem to have been thrust up at a period anterior to the passage of the great lava-stream, inasmuch as they rise up suddenly from the general level, and thus indicate its gradual elevation around their bases. But at the present day there remains no direct evidence to show from whence the stream flowed. The distance of its central portion from the two great southern foci of convulsion, namely Hecla and Eyefialla, is about sixty miles. It is nevertheless quite possible that it may have flowed from one of these, inasmuch as, during the eruption of Skaptar Jokul in 1783, two streams were given off, one of which extended to a distance of fifty miles, with a breadth varying from twelve to fifteen miles, and an average depth, where spread out on flat tracts, of 100 feet; whilst the other reached to a distance of forty miles, with an average breadth of seven miles, and the same depth as the previously mentioned stream. But in some of the gorges, between the mountains through which these streams forced their way, they actually attained the enormous depth of upwards of 600 feet.

The shore along the fiord near Rekiavik is composed entirely of huge scoriaceous blocks of lava, the colours of which vary from a slaty blue, to purple, brick-red, and black. All are more or less spongy in their structure, and, except where they have been subjected to attrition within the tide-marks, retain the sharp irregular emery-like surface so characteristic of the lavas and pumice masses. Even the small boulders and pieces of shingle along the water-line, which have been subject to long-continued violent attrition against each other, although rounded in outline, present the same peculiarity; whilst the resultant

sand consists of minute angular particles which never lose their primary keenness, under any amount of comminution. The same remark applies to the more glassy obsidian-like substance of which the soundings on the southern coast consist. This deposit has been derived, in all probability, from the atmosphere during the eruptions; and it is somewhat extraordinary that it should be almost entirely free from particles of true lava or pumice. So far as the soundings have hitherto gone, this peculiarity is invariably observable. It would therefore appear that the clouds of volcanic dust with which the atmosphere is loaded, and which has been known to extend to the coasts of Norway, the Faröe Islands, and even Shetland, constitute the true basis of the molten mass of the volcano, the lavas and pumice being the overflowing scum that collects upon its upper surface.

As far as I have been able to learn from persons who have travelled in the neighbourhood of the obsidian veins, these do not occur at great elevations on the sides of the volcanic cones, but appear suddenly and end as suddenly. Should this really prove to be the case, it would indicate that the streams of obsidian were poured out through lateral channels, situated below the level at which the fused mass within the body of the volcano assumes its frothy character. Pent up as is the gaseous matter within the cellular cavities, under an inconceivably vast pressure, it is easy to perceive that such portions as are thrown up from the mouths of the crater itself would be shivered into innumerable minute atoms on escaping into the atmosphere, and, in this state, be borne far and wide with its currents.

Out of 25 soundings made up to this date, bottom has been brought up, in greater or smaller quantity, seventeen times. Of this number 10 soundings have been effected with the greased sinker, and 5 with the conical cup.

I have devised, and submitted to Sir Leopold M'Clintock, a modification of the "Clams" which he described to me as having been employed by Sir John Ross many years ago. Instead of clams I have suggested *cups*, closing on hinged levers, and available with the hollow Brooke's sinkers supplied for use on board the 'Bulldog.'

July 13.—Called on the leading residents at Rekiavik, and experienced from them the cordial hospitality for which they have always been remarkable. The name of the ship seemed to afford the little community a standing joke as being peculiarly applicable to "John Boole." It is only to be hoped that their ideas

of our refinement were not based on the grinning demon that passes muster as a figure-head, and vouches for our "fancy" habits by having its neck encircled with a huge saw-toothed collar.

Dr. Hjalthelin, the chief surgeon of the settlement, whose acquaintance I had the pleasure of making today, informs me that Kotla (the volcano which burst into action in the middle of May) is one of the largest in the island. For some weeks prior to the eruption, the wells and springs dried up and several shocks of earthquake were experienced. Towards the end of May, it cast forth vast masses of lava and *ice*, mixed. This is precisely what Sir Charles Lyell states might be expected to take place in the case of the Icelandic volcanos, the cones of which are more or less constantly covered with perpetual snow*,—his conclusion being based on the discovery on Mount Etna, in 1828, by Signor Gemmellaro, of an extensive glacier *over* which had flowed the lava-current. "We may suppose," writes Sir Charles, "that, at the commencement of the eruption, a deep mass of drift-snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ is well known to be an extremely bad conductor of heat. . . . . Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had consolidated, we may then readily conceive that a glacier thus protected would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below."

In the recent eruption of Kotla these several conditions would seem to have been fully answered. It is well known that the summit of the cone of this mountain was completely encircled with glacier. During the earlier period of the eruption the ejected matter consisted principally of small scoriæ, with immense volumes of dust, by which the atmosphere was darkened. It is therefore highly probable that a considerable layer had time to collect, and thus to protect from immediate disruption the great mass of ice occupying the depression of the crater. On the eruption attaining its height, this mass would be rent asunder, in the first instance, into innumerable blocks of still gigantic proportions; and finally these blocks, melting and being dislodged by the intensity of the temperature, would flow towards the vents and there mingle and be ejected with the general mass of volcanic matter.

* Lyell's 'Principles of Geology,' 1853, p. 413.

During the continuance of the eruption, great sickness and mortality are said to have occurred amongst the inhabitants of the islands and their cattle. Forty thousand sheep perished in the short space of six weeks. Similar results are recorded as having attended previous outbursts. They are referred to, not as secondary results of the phenomena, but as being directly and entirely due to the dissemination of mephitic vapours. Now although the gaseous products of volcanic action are no doubt highly deleterious, I cannot help thinking that an undue amount of direct influence is supposed to attach to them. Leaving out of the question the effect on the animal economy of inhaling minutely pulverized particles of mineral matter of any kind—effects which can be demonstrated too frequently amongst our own manufacturing towns, without having to seek for illustrations in volcanic regions—I think it highly probable that fear and mental depression must be regarded as the mephitic influences most potent in the production of the evils. No more conclusive proof is needed of the wonderful extent to which fear may operate, than the almost universal sensations of "sickness" and "giddiness" said to attend an earthquake. As the shocks rarely last above a minute or two, it is obviously absurd to refer these sensations to any more palpable cause than alarm; and we may readily understand, therefore, how such sensations, if protracted for considerable periods, and aggravated by the intensity of the predisposing cause, may bring about the most alarming or fatal consequences.

CHAPTER II.

LEAVE REKIAVIK.—LIMITATION OF VOLCANIC DEPOSIT.—ITS SUPPOSED CAUSE.—SOUNDINGS.—ABSENCE OF MINUTE ANIMAL LIFE AT SEA-SURFACE.—BROOKE'S APPARATUS.—VALUE OF CAREFUL MICROSCOPIC EXAMINATION OF SOUNDINGS.—UNUSUAL ATMOSPHERIC APPEARANCE.—FIRST GLIMPSE OF GREENLAND.—PACK-ICE AND BERGS.—DEPTH OF SEA BETWEEN ICELAND AND GREENLAND.—GREAT EXTENT OF ICE-PACK.—HEAVY GALES.—GREAT GLACIER.—TALLERT BANK.—UNABLE TO REACH FREDERICKSHAAB.—RAPID DRIFT OF ICE.—SHIP SUDDENLY HEMMED IN.—RETURN TO TALLERT BANK.—FALL IN WITH OUR COLLIER.—RENEWAL OF ATTEMPT TO MAKE FREDERICKSHAAB.—PROCEED TO THE NORTHWARD.—BAAL'S RIVER.—ARRIVAL AT GOODHAAB.

July 15.—Left Rekiavik yesterday forenoon just as the clouds, which had so invidiously hung over the island during nearly the whole period of our stay, began to break and give promise of returning sunshine. But the mists still surrounded the whole of the mountain-ranges, and Iceland faded from our sight much after the same provoking fashion that the Faröes did.

Soundings have been taken at intervals of two hours; and as each one is invariably examined by me the moment it is brought on board, I had rather too much science and too little slumber during the night. Having traced the range of the volcanic deposit to the eastward of the island, it becomes a matter of great interest to find out how far it extends in the direction of Greenland. This I shall now have a double opportunity of doing, as the 'Bulldog' is to return to Rekiavik on her home voyage.

The soundings already taken reveal a very curious fact, namely, that all trace of the fine volcanic mud which constitutes almost the entire mass of the bottom deposit between the longitudes of 14° 40′ and 23° 02′ (the latter representing a point distant about fifteen miles from the western shore we have just left) ceases along a tract of about forty miles. Along this interval it is replaced by rounded basaltic gravel; but at a distance of about sixty miles from land it re-appears, in reduced quantity and a much more comminuted condition, as a slate-coloured mud. From this point the traces grow fainter and fainter, until in long. 27° 33′ they are altogether suspended, the depth of water being 819 fathoms.

At present I am unable to hazard even a supposition as to the source whence the basalt is derived. The shape and smooth surface of the pieces clearly seem to indicate a current or tideway. It can hardly come from Breda fiord, inasmuch as in passing across Faxe fiord it must have become associated with the volcanic mud of which the bottom of that fiord is formed. On the other hand, it is highly improbable that it has been deposited by floating ice, inasmuch as the tract along which it occurs is precisely that most free from ice. But wherever its source, the occurrence of such a well-defined interruption in the volcanic deposit, coupled with the character of the basaltic gravel present in the interval, seems irreconcileable with any other explanation than the one suggested, namely the transporting and abrading action of a bottom current. But to this subject I hope hereafter to be able to revert.

July 16.—For the first time since leaving the Faröes, the morning has been ushered in with a clear sky, calm water, and a bracing but not chilly atmosphere. Last night it was both cold and raw. The depths are gradually increasing, each sounding exceeding the previous one by about one or two hundred fathoms. At 8 P.M. a sounding was made at 1377 fathoms, but with a greased sinker. A boom was rigged out for me today, in order to try whether my surface-nets could be used clear of the disturbed water produced by the progress of the ship. But although the day was bright and the surface calm, and the objects of my solicitude were no doubt disporting themselves on all sides, the speed was an effectual obstacle to success. It is evident that, unless under sail only, any attempt at surface operations will be futile. In a screw steamer it might perhaps be possible to use the net, by having a boom rigged out from the waist or forecastle; but in a paddle ship it is out of the question.

July 17.—Depth still gradually increasing. Brooke's machine has been employed for the second time today. In sounding No. 28, about twenty miles from Rekianess, it was let down, but failed to bring up a specimen of bottom, although the depth was only 80 fathoms. Today, it only partially succeeded, bringing up about half an ounce of mud. Had the construction of this apparatus been suitable, a much larger quantity must have come up. What there was I found sticking to the inner side of the cylinder at the point at which it is screwed on to the shaft. All between the screw and valve had been washed out,—there being a direct communication between the lower valvular aperture and the entire

length of the shaft, which, as a matter of course, causes a current to flow from one end to the other, in hauling up, should there be the slightest inaccuracy in the valvular fitting. In the event of the valve being jammed by the insertion of mud or anything else between the spring and the side of the cylinder, the same untoward effect would be produced. The material brought up is nevertheless of interest, being the first example of the so-called deep-sea "ooze."

A boat was placed at my service today during two of the soundings. But although the weather was fine, the surface was too rough to use my nets with success. We saw several whales, some of very large size.

July 18.—The value of careful microscopic examination was shown in the case of a sounding taken last night. A Brooke's appa.atus was let down and carried away. A second, entirely new, was then employed. It seemed to come up quite clean and empty. At one point, however, a minute grey speck of mud was discernible adherent to the cylinder. This was cautiously separated, and on being placed under the microscope proved to be mud. The quantity brought up was not quite one-eighth of a grain.

Shortly before noon, a most unusual gloom seemed to spread over sea and air and sky. Overhead reigned a dense leaden tint, as if the sun had been put in with Indian ink and then clumsily rubbed out. Around the horizon stretched a murky solid-looking wall of mist or cloud which had the appearance of closing in upon us on every side. The barometer indicated no unusual atmospheric disturbance; but the Kittiwakes and Jäger Gulls, that had been hovering about the ship, seemed as sorely puzzled at the prospect as we were who stood discussing the peculiarities of Greenland weather. The Master, who was taking his meridian altitude, possibly shared our perplexity. If he did so, he certainly kept his own counsels like a wise man, until he solved the mystery by bringing to our recollection—that *the* eclipse was going on.

July 19.—Today I have seen a sight that outstrips the power of imagination to picture, or words to describe. Rather less than a week ago we were surrounded by the evidences of igneous cataclysms of stupendous magnitude. We are now rapidly approaching a region whose surface has, for ages past, been the theatre of glacial cataclysms quite as stupendous.

Early this morning the east coast of Greenland was sighted, at a point about five-and-twenty miles distant from Cape Vallöe. The atmosphere was as clear

as crystal, the sea as unruffled as a mirror; whilst the blue tint presented by both was of an intensity rarely equalled except in subtropical latitudes.

Before us stretched in a long line, extending as far on either side as the eye could reach, the rugged mountain-ranges that hem in the eternal desolation beyond. No gentle slope mingled with the outline of the innumerable icy peaks which stood out against the horizon with an almost terrible distinctness, but everywhere was to be seen the stern grandeur of a scene beside which the snowy ranges of the Himalaya, majestic as they are, would appear subdued into tameness. Between the ridges, the snows of centuries had already filled up the chasms, and hid from view all but the most perpendicular faces of rock. No portion of the shore-line was visible; yet its position and direction could be determined by the differences in character of the fixed and floating ice. From it, to within a short distance of the ship, extended a dense mass of closely aggregated pack-ice, out of the midst of which, at intervals, huge bergs reared up their glistening sides, whilst, floating clear of the pack, detached masses were to be seen whose battered condition plainly told of many an Arctic blast and wave. Some of the bergs were of gigantic size, and exhibited a regularity of form almost unaccountable. Others, again, seemed as if they had been fretted and contorted into every possible shape. The further we advanced, the more numerous the bergs became; and in passing near them we could detect the exquisite colouring of the water-washed portions as contrasted with the virgin whiteness of the upper walls. Such tints of soft blue and green no other hand than Nature's could impart, such contrasts of light and shade where apparently there was no colour, and such contrasts of tint where it was impossible to detect a shadow. But the attempt to describe such a scene is vain. The eye may gaze upon it and admire; but the soul, as if conscious of God's presence, bows down in adoration and is speechless.

The total number of soundings taken between Iceland and the east coast of Greenland was thirty. Assuming the entire distance between the two points to be, in round numbers, 600 miles, this would give an average interval of twenty miles from sounding to sounding. The mid-channel soundings, however, were about fifty miles apart.

The greatest depth, namely 1572 fathoms, was encountered halfway across, the descent being apparently very regular down to that point. As already noted,

all trace of volcanic particles was lost about one-tenth of the distance across, in long. 25° 07′.

The ascent from the deepest recorded sounding (which was in long. 32° 34′) was equally regular up to a point about fifty miles distant from the east coast of Greenland. But here a very sudden and remarkable rise was met with—the depth decreasing from 806 to 227 fathoms in three and a quarter miles; that is, at a rate of 1050 feet per mile.

The greatest dip on the mid-Atlantic route occurred, as is well known, near the Irish coast. It was at the rate of 720 feet per mile. The respective ratios of these two great dips are, as 1 to 5, and 1 to 6, and represent angles of eleven and nine degrees.

In attempting to dredge today in 108 fathoms water, whilst a sounding was going on, my dredge got foul of rock at the bottom and was lost. This is a serious accident, inasmuch as it was the only apparatus of the kind I was enabled to procure before leaving England. Had it been made of gold, instead of the baser metal, the loss could hardly have been more keenly felt at the present moment.

I have already alluded to the uncertainty of action in Brooke's sounding-machines. But the experience derived from some of our recent soundings suggests doubts in my mind as to whether the results obtained by any of the methods of sounding hitherto employed can be relied on as affording a correct estimate of the character of the sea-bed.

On the occasion of the dredge being lost, it was dropped over the stern, whilst the sounding with the conical cup was being conducted in the usual place, namely over the bows. The cup came up half full of grey mud, pieces of granitic and felspathic rock, varying in size from a quarter of an inch to an inch, and some fragments of a delicate coral. From indications present on the pieces of rock, it was perfectly clear that they were resting on the bottom as gravel or shingle, and that they were not broken off by the machine from the strata forming it. On the other hand, it was equally certain that either exposed rocky strata or very large detached masses of rock constituted the bottom, inasmuch as the strain caused by the fouling of the dredge was sufficient to snap asunder the perfectly new deep-sea-line attached to it, and which was capable of bearing a weight of several hundred pounds.

Our first day amongst the ice terminated with a sunset worthy of the majestic mountain scenery over which it shed its gorgeously-tinted rays. If the old saw be correct, we may look out for "dirty" weather tomorrow.

July 20.—It blew hard during the night; and but for the pack-ice, which befriended us, we must have had a far more boisterous sea. For the first time since approaching the Faröe Islands, the endless day has been interrupted by a couple of hours of twilight, during which a few stars ventured out like modest virgins, and then hastily retreated as if in alarm at their own temerity. During the day and so long as the air was still, the temperature, although bracing, did not feel perceptibly lower than that of a fine day in November in our own latitudes. But as we neared Cape Farewell, the air began to feel bitterly piercing, the sky was overcast, and we were so closely surrounded by ice that the ship had to be put considerably to the southward of her course.

We are now well out to sea again, out of sight of land, and with ice all round. After proceeding to the northward till about 9 A.M., the pack became too dense to admit of our advancing, and accordingly the 'Bulldog' is compelled to retrace her steps until clear water shows itself.

July 22.—The ship is now heading to the north-westward at the entrance to Davis Straits, in order to get clear of the pack, and is to continue on this course till abreast of Frederickshaab, a Danish settlement on the west coast of Greenland, about 180 miles from Cape Farewell, where a vessel has been directed to precede her with a supply of coal. The barometer has been steadily falling during the whole night, and now stands at 29·17. A heavy gale blowing.

July 23.—The ship "lying to" all night under storm jib and close-reefed topsail. There is a tremendous sea running, and in it the 'Bulldog' wallows to her heart's content. Everything in my cabin adrift, and apparently intent on mischief. As any endeavour to restore order in such a turmoil would only be to establish a fresh point of "departure," I must rest content to let the riot continue for the present. Writing, under these circumstances, not only demands some skill in equitation, but has to be done by catching a propitious interval between each surge—much in the same fashion that the engineer uses the oil-can in those parts of the machine near which, were his hand to remain an instant too long, it would be crushed into mincemeat.

July 24.—Land in sight all the forenoon. At 5 P.M. we were off the "Ice Blink," or Great Glacier, about thirty miles to the northward of Frederickshaab. This gigantic mass of ice is said to be twelve miles in diameter, although, from the circumstance of its forming a curve, it appears considerably less. On either flank, the lofty mountain-ranges slope down and form the broad valley on which the glacier rests. Far back in the distance some bold peaks rise suddenly from the general mass, and mark its boundary in that direction; whilst stretching across an arc of twenty degrees, and at a probable distance of not less than thirty miles, the still unbroken contour of the mighty glacier cuts the horizon.

But, withal, the scene is tame, and, compared with that observable on the eastern coast, almost uninteresting. The long regular sweep of the surface of the glacier is unbroken save by the innumerable little channels worn into it by the melting of the upper layer during the short northern summers, and, instead of presenting the pure whiteness of the peaks on either side, is stained and muddy from the deposits that have taken place upon it. Seen from a distance of ten or fifteen miles, the angle of inclination appears exceedingly small; and along the shore-line the vast mass descends so gradually as to afford no indication of the point at which it terminates and the land-ice begins. According to Crantz (Hist. Greenland, translated from the Danish: London, 1820, p. 5), "The "points of land, which run out a great way into the sea on both sides, consist "of banks of sand so fine and light that, when agitated by the slightest breeze, it "darkens the air like a cloud, and fills the eyes and mouth of all who approach "within eight leagues of the shore." This accounts for the peculiar colour of the surface of the glacier; but it is somewhat remarkable that, although the narrator of the above fact visited the "Ice Blink" at precisely the same period of the year as we did, no other trace of the presence of this dust-bank was observable.

An extensive shoal, called the "Tallert bank," reaches out to sea for many miles in front of the great glacier. I was extremely desirous of ascertaining the character of the deposit constituting this bank; but the state of the weather and ice afforded no opportunity. This is the more to be regretted, as, from the appearance and form of the glacier, the fact of its never "calving" (that is, giving off bergs), and the existence of an extensive shoal, I am inclined to believe that the glacier now under notice covers a large river which takes its rise in the far interior, and debouches below low-water mark, bringing with it

the detritus to build up the bank. Under no other set of conditions does it seem possible that such a shoal should form. The fact of other glaciers both on this and the east coast giving off bergs is of itself proof of the presence of deep water, inasmuch as the stranding of masses of sufficient size to offer resistance to the downward progress of the glacier itself would inevitably be overcome in time by the accumulated pressure. The first operation of this pressure would be to heap up a pile of gigantic bergs. Gradually it would overcome the resistance of these and hurl them onwards, ploughing out chasms in the sea-bottom, and eventually creating channels of sufficient depth to float the detached masses subsequently given off. By degrees the boundary-walls of these channels would be broken up and deposit their silt along the deepest portions. Again obstruction would take place by the grounding of the bergs. Again the channels would be cleared. Again the silt would be deposited, but in diminished quantity,—until at last, under the combined and long-continued repetition of these causes, the depth of the sea-bed would become sufficient to permit the unimpeded descent and advance of the newly-detached bergs. If we bear in mind that these ice-masses do not glide into the sea from their parent glacier, like Naiads gliding into a crystal lake, but plunge headlong with a crash which raises the water around into a perfect tempest, extending for several miles, and that the detached mass does not recover from its drunken gyrations for days after leaving the land, we shall be able perhaps to form some estimate of the stupendous force that an accumulation of these masses would engender.

In Crantz's narrative already referred to, he gives an extract from a communication made to him by an old Danish factor who had resided many years at Frederickshaab. Speaking of the difficulty of accounting for the immense quantities of ice discharged from Disco Bay, the narrator says, "I received "some explanation of this difficulty from a journey I made with some Green- "landers along the 'Ice Blink Bay' as high up into the interior as any Green- "lander had ventured. I then discovered that, though nothing but firm land "coated with ice appears seaward, there may still be open water on the land side. "I also learned the manner in which the fragments of ice are carried down into "the sea by the current, *under the solid surface.* When and how the mouth of "the bay was blocked up, is unknown. Probably, during a long season of calm "weather attended with severe frost, in the middle of winter, the drift-ice may

"have continued stationary at the mouth of the fiorde, and being exposed in spring "to an alternation of thaw and frost, have been consolidated in a mass firm enough "to resist the summer's warmth, and the action of the winds and current. The "frozen snow accumulating for ages has swollen this mass to so huge a bulk, that "the narrow arches through which the stream impetuously rushes are in many "places 20 fathom high. The pieces of ice yearly precipitated from the moun-"tains into the open bay are hurried down by the stream upon this icy bridge. "The smaller fragments float through; the larger dash against it until they are "broken into pieces small enough to pass through also*."

Now, although the character of the glacier must have undergone great modification since the period to which the above account refers—no less than 104 years ago—inasmuch as its sea-margin does not rise to half the height to which the arches are stated to have reached, there is quite sufficient evidence to show that a vast subglacial efflux of water must have been present at that date.

July 25.—After steaming slowly to the southward all night, it is found that the passage into Frederickshaab is impracticable. The whole coast-line is blocked up with an impenetrable barrier of ice extending for many miles out to sea. It is usual for the coast-ice to begin to disappear considerably before this period; and as the movement takes place from the northward, it is but too probable that the settlements to the southward, namely Julianshaab and Nenortalik, are equally unapproachable. The collier therefore can hardly have reached either of these places. I believe we have one week's supply of coal left. The barometer is again falling rapidly, and already it is blowing a gale. So once more we are off to sea. Towards evening steam shut off, and ship under sail only.

Besides the main body of the pack hemming in the coast as a long unbroken barrier, a number of bergs of very large size are to be seen on every side. These vary in height from 50 to 150 feet or even more. One appeared to be about 200 yards in length. The detached pieces of pack generally indicate a thickness of from 15 to 20 feet, whilst in diameter they are at times as much as 100 yards. A curious appearance is observable in some of the bergs. As already mentioned, the entire mass above water is generally of the purest whiteness, there being little or no transparency visible until within a few feet of the line of floatation. But in some bergs delicate yet well-defined lines may be seen, of a rich ultra-

* Crantz, 'History of Greenland,' p. 19.

marine colour, traversing the faces from side to side or from top to bottom. At a little distance these lines look like fissures; and so in reality they are, although completely filled up with transparent ice, which contrasts strongly with the pure whiteness of the body of the berg. It is probable that these fissures have occurred prior to the separation of the berg from the parent glacier, and that the transparent streaks of ice are due to the infiltration and congelation of fresh water which has flowed into them; for, had they occurred subsequently to the separation of the bergs, the split portions must have fallen asunder. The nature of the blue streak was clearly exhibited in a berg the nearest face of which appeared to have been recently split off. In this case the summit of the mass was somewhat concave, or rather had been concave, before the face alluded to fell asunder from it; and towards the central portion of its upper edge was to be seen the sectional view of a trough, from the base of which the blue streak extended down to the water's edge, both the trough and the fissure proceeding from it being filled up with a beautiful clear blue vein of ice. Here, then, it is evident that the infiltration of water into the fissure, and the trough-like cavity from whence it sprung, were due to the thawing of the upper surface of the berg.

July 27.—There is something singularly deceitful in these northern summers. For a few hours last evening the sky shook off the foggy mantle it had assumed the day before and gave token of returning sunshine. The wind lulled almost to a calm, and with it the sea. But it was only to take breath and recover their energies for another hubbub. The glass fell rapidly after midnight; and by 6 A.M. the gale was blowing as fiercely as ever from south-west, the quarter of all others the most certain to accumulate more drift-ice along the coast, and impact it into a denser barrier than ever.

Last evening, the moment the state of the sea admitted, I let down my surface-nets; but, with the exception of the common forms of *Entomostraca*, some ciliograde Medusæ and an Annelid closely allied to *Tomopteris* (Esch.) (the *Johnstonella* of Gosse), I captured nothing.

July 31.—The weather having moderated somewhat, yesterday afternoon the ship started under steam once more for Frederickshaab. The scattered state of the ice through which we passed this morning induced a hope that the coast might now be sufficiently clear to allow of our entrance. But we are doomed to disappointment; for after forcing our way, in a dense fog, through many miles

of drifting ice, we sighted Little Vardoe (the island lying a few miles seaward of the settlement), and found any nearer approach as impracticable as before. It is evident, therefore, that instead of the vast fields of drifting ice through which we have had to thread our way being the dispersed remnant of the pack previously blocking up the coast-line, they were fresh reinforcements brought up by the strong south-westerly gales. In ordinary seasons the current from Cape Farewell is of sufficient strength to keep the channel between Little Vardoe and the mainland clear of ice, even when the rest of the coast is hemmed in. It is evident, therefore, that exceptional influences are in operation this year.

During a sounding taken at 2 P.M. in 100 fathoms, the rate of this current was made apparent by the rapid manner in which the 'Bulldog' drifted towards an immense grounded berg, in order to escape collision with which, the engines had to be backed.

The berg in question was about 120 feet in height. As the ship passed within a hundred yards of it, I could perceive that, from the water-line, the mass diminished rapidly in diameter and sloped upwards at a considerable angle on all sides, whilst immediately below the surface it spread out horizontally for many yards.

I am indebted to the kindness of Mr. Roughton, the chief engineer of the 'Bulldog,' for having replaced my dredge. It has been on its first voyage of discovery, and brought up some interesting specimens of Corals, Polyzoa, and Ascidians,—the latter presenting the velvety tinting of a ripe peach, some of the former so delicate and fragile as to demand the most careful handling; and yet every inch of the sea-bed on which they rest must now and then be ruthlessly ploughed up and crushed beneath the icy mountains that traverse these waters!

Again the 'Bulldog' turns her head seawards, but under sail only, inasmuch as it is more than ever imperative to economize the little remaining stock of coal on board. Passed through immense quantities of ice and saw some gigantic bergs. About fifty miles from land, one of these, at least 180 feet high, was stranded, whilst the surface-current set so strongly towards it that it brought up a vast compact field a distance of two miles in half an hour. The terrific crashing of this moving mass was distinctly audible at a distance of three miles. Notwithstanding the tendency of a bitterly cold Arctic drizzle to strangle every spark of sentiment in its infancy, "imagination bodied forth the forms of things unknown," and

I saw before me a superhuman host rushing on to the assault with a yell that might make hell tremble, whilst a beleaguered garrison, conscious of the impregnability of its position, awaited the assault in stern and silent defiance.

At this stage of the melodrama, the fog overcame both imagination and reality, and the fortune of the day remains a mystery.

In the evening the ship was suddenly hemmed in by ice; and in order to extricate her from this perilous position, she had to make a "stern board." Of course it was admirably managed, and in a few minutes we were again in clear water.

Aug. 1.—Fine weather for once. Sounded for depth, which was found to be 700 fathoms. Lat. 62° 3′, long. 51° 10′.

Aug. 3.—Stood in towards the land, making the Tallert bank again, immediately off the Great Glacier. The day was beautifully fine, and gave us an opportunity of forming an estimate of the state of the ice. The pack seems much broken up, and is taking a north-westerly course seawards the wind being off shore. In a northerly direction the ice does not seem to extend beyond half-a-dozen miles. Inshore there is still a considerable quantity; but, from the heavy crushing roar caused by the pressure of the masses against each other, it seems probable that the whole pack is commencing to move away. The sound referred to is unlike any other I have ever heard, inasmuch as it seems to proceed equally from the entire coast-line within view, and, although loud and distinct, conveys the impression of being felt rather than heard.

The Glacier looks as undemonstrative as ever, and grand in its stolidity.

The pack is reported to extend southwards as far as the eye can reach; but, on our skirting its well-defined margin for some miles, the body of the ice is observed turning off seawards about halfway between us and Frederickshaab. Already it stretches out from land some twelve or fifteen miles. There are "lanes" and patches of clear water to be seen within the pack; but none of these are of a nature to warrant the attempt to force a passage through them—at all events not in a paddle-ship.

In the afternoon a brig was reported in sight, some fifteen miles off, standing to the southward. She proved to be our collier. Her master states that he arrived off Frederickshaab on the 18th of last month, but, a terrific gale coming on, he had to run out to sea again, and was eventually driven so far up to the northward that he has only now been able to effect his return.

Aug. 4.—Once more an unsuccessful effort has been made to reach Frederickshaab, the entire coast being still blocked up with an impenetrable barrier of ice. The 'Bulldog's' head is therefore turned northward, and, with the 'Cicerone' in tow, she goes in quest of a more hospitable port higher up Davis Straits.

Aug. 5.—We passed through a very large quantity of pack-ice yesterday, and met with some unavoidable concussions, but no serious injury. The day was tolerably fine, and afforded us an opportunity of seeing several magnificent peaks and glaciers on the coast. Although none of the latter are comparable, in point of extent, with the great "Ice Blink" near Frederickshaab, they far outstrip it in scenic grandeur. In one instance, the abruptly terminated face of the glacier clearly indicated the recent projection of several bergs.

It rained all night. At an early hour the 'Bulldog' was close in shore. But the sudden fall of the barometer, and the advent of a heavy swell from the southward, rendered it necessary to run out to sea without a moment's delay. By 9 A.M. the wind had already increased to a gale. The 'Cicerone' was being fairly dragged through the seas, which swept her deck from stem to stern. The strain becoming too great, the hawser parted. For a few moments the little vessel staggered, as if in hesitation whether she should go down head first or capsize. But she was too skilfully handled to yield even in the presence of such danger. In the twinkling of an eye a close-reefed topsail was set, and under it and a jib, which had providentially been hoisted before the tow-rope gave way, the gallant craft dashed off to windward and was soon lost to view in the distance.

Aug. 7.—Yesterday forenoon, the gale having moderated, the 'Bulldog' stood in towards land, and made it some miles to the northward of Baal's River. This morning she steamed down along the outer margin of the innumerable rocky islets that gird the coast, and arrived at the mouth of the inlet about 10 A.M., escorted by a small fleet of Esquimaux kayaks.

Although there was less ice along the portion of the coast we had traversed to the northward than had been met with in the direction of Frederickshaab, the entire surface of Baal's River and the fiords branching off from it, was covered with such a dense mass that it was with great difficulty, and only under the exercise of the utmost skill, that a passage through it was effected. About 4 P.M. the 'Bulldog's' anchor dropped in the harbour of Goodhaab.

CHAPTER III.

HARBOUR AT GOODHAAB. — BESET IN THE ICE. — AMERICAN ENTERPRISE. — DANISH SETTLEMENTS.—SEVERITY OF SEASON.—DEPTH OF FIORDS.—DREDGING UNDER DIFFICULTIES.—METHOD OF DETERMINING IMMERSION OF ICE.—BOULDERS.—MOUNTAIN TARN.—MICROSCOPIC ALGÆ.—ESQUIMAUX AND THEIR KAYAKS. — OOMIAKS. — DEPARTURE FROM GOODHAAB. — FREDERICKSHAAB AGAIN.—CAPE DESOLATION.—ICE AND ICEBERGS.—SOUNDINGS ACROSS DAVIS STRAITS.—ANCHOR IN HAMILTON INLET.

After being tempest-tossed for nearly three weeks in the midst of an ice-covered sea, it is pleasant to find ourselves, in company with four other vessels, resting placidly in a land-locked bay, over which the Arctic blasts may blow their fiercest, but whose surface they would find it difficult to arouse into any greater commotion than a ripple. On three sides it is encompassed by steep hills rising up to a height of several hundred feet, with deep water extending almost to their bases. On the fourth, a long spit of rock stretches to the westward and overlaps a bluff headland that closes in the harbour from the fiord outside. Away to the southward, the peaks of "Hiorte Tok," or the "Stag's-horn" mountain, rise above the boundary-walls of our anchorage, whilst an intermediate range sweeps round the eastern margin of the broad fiord, from which it is separated by the spit already referred to.

The other vessels consist of a couple of Danish barks of about six hundred tons burden, come in here for shelter until the state of the ice admits of their going into a southern port to load with cryolite; a smart-looking American schooner, carrying a living cargo of fifty students of Williams' College, Massachusetts, bound to these parts on a scientific excursion, under the superintendence of Professor Chadbourne; and lastly our collier brig.

The American was strenuously endeavouring to beat up the channel as we steamed in, but was baffled by the immense quantity of ice about. At the request of her Captain, who came on board, she was towed in to the anchorage by the 'Bulldog.'

Aug. 8.—The scene around us today is both unexpected and interesting.

We are completely beset in the ice-pack, which has been streaming in uninterruptedly from seawards ever since our arrival, and may be seen from the masthead still pouring in at the entrance to Baal's River. In the harbour the masses are crowded together in such close order as to render it impossible even for a kayak to move amongst them; whilst the constant rolling over of pieces here and there, owing to the crushing pressure to which they are subject, effectually bars any attempt at passing to and fro on foot.

The whole of the ice appears similar in character to that by which we have been so hampered lower down the coast, and is of too great thickness to have been formed in the fiords on this side of Greenland. The pieces vary from 3 feet in superficial diameter to 40 or more. But in thickness above the water-line there seems to be much greater uniformity, the range being from 2 to 6 feet. Interspersed amongst this pack-ice are a few small bergs, not rising above 10 or 12 feet from the surface, and in all probability fragments of larger masses.

Strange to say, although the temperature of the water at the surface is only a few degrees above freezing-point, wherever a clear space of a few inches intervenes between the pieces of ice, delicately tinted Medusæ and glistening Beroidæ may be seen struggling upwards from the depths to bask in the sunshine of which they are being so rudely deprived,—whilst numbers of mosquitos, active enough to have emerged from a tropical forest, buzz through the air and evince their sense of its warmth by bloodthirsty attacks on all new comers. Nature for a time seems to search for contrasts. Above, an Italian sky; below, an Arctic sea; as if Summer had stolen away from the soft South to smile on Winter in his grim domain.

Aug. 10.—The partial clearing of the ice today has enabled me to reach the 'Nautilus' and make the acquaintance of Professor Chadbourne, from whom I had received a very polite message. I learn from him that the expedition, of which he is the director, is a private one, the entire expenses, even to the chartering the schooner, being liquidated by the students or their friends—the object in view being to teach them how to observe and collect specimens in the various departments of Natural History. The 'Nautilus' left Thomaston on the 27th of June, and, after dropping a small party, *en route*, at Labrador, reached the Greenland coast, off Julianshaab, the same day that the 'Cicerone' reached the neighbourhood of Frederickshaab, and experienced the full force of the gale

alluded to by the master of the latter vessel. It may be recollected that on the east coast of Greenland, in almost the same latitude, the 'Bulldog' experienced calm weather on the eclipse day, and that it was not until she had rounded Cape Farewell and emerged from the shelter of the land that the south-westerly storms burst upon her.

Professor Chadbourne informs me that on the morning of the 18th of July the 'Nautilus,' in endeavouring to make the land off Frederickshaab, met with an immense belt of pack-ice a hundred miles from shore, from which she had barely time to escape when the gale suddenly increased to a perfect hurricane. Running northward before it, in a couple of days the schooner was enabled to round the advanced extremity of the pack, and to anchor in a little harbour in the vicinity of Sukkertoppen, a small settlement about eighty miles due north of Goodhaab. But for the absolute necessity of obtaining the supply of coal directed to await us at Frederickshaab, the 'Bulldog' might therefore have been comfortably ensconced at a like early date.

There are two small stations here, situated near the north-western angle of a rather low peninsula, of nearly a mile in breadth, which abuts on Baal's River, and separates our present harbour from it to the northward. At one of these, namely Hernhutt, the Moravian Missionaries reside, whose predecessors, more than a hundred years ago, established the first colony in the country. At the other, Goodhaab itself, the superintendent of South Greenland (Dr. Rink) and the principal merchants are located. On the eastern side the little peninsula is united with the mainland by a series of hillocks, which gradually increase in height as they approach and sweep round the inner margin of our anchorage; whilst along the shore-line it is protected, by a natural rampart of gneiss-rock, from the waters of Baal's River and the adjacent fiord, which would otherwise inundate it.

The Danish residents inform me that such a severe season has been unknown in Greenland for thirty years, and that the quantity of ice far surpasses that usually met with. On the other hand, it is a remarkable circumstance that the quantity of drift-wood brought round with the ice from Cape Farewell is far below that met with in average seasons. This can only be accounted for on the supposition that the range of the Arctic current, as it sweeps across from Nova Zembla and Spitzbergen towards East Greenland, has been so far extended to

the southward as to overpower and deflect that portion of the stream which bears the drift-timber across.

Aug. 12.—Whatever may be the aspect of Greenland in its winter garb, or under lowering skies, it is a very enjoyable place on a bright day in August. Notwithstanding the scanty nature of the vegetation, there is quite enough verdure observable to soften the asperities of the landscape, whilst the brilliant sun and pure atmosphere impart a degree of warmth to its colouring that is heightened, instead of being destroyed, by the cold whiteness of the ice-covered fiords.

The quantity of ice is somewhat less today; but it fluctuates so rapidly as it happens to be influenced either by the wind or tide, that it is impossible to foretell one hour what may be the state of the fiords the next. Yesterday the pack streamed in so suddenly, that a large party of the Danish residents who had come round from the colony, by boat, to visit the ship, were obliged to make their way home in the dark, across a mile of heavy swamp.

The temperature in the middle of the day is producing marked effects on the ice. On every side the ear catches the sound of the melted drops as they trickle from the projecting ledges into the water. Many of the pieces seem already to be honey-combed, and break up when subjected to pressure by the surrounding masses, the immediate alteration in their centres of gravity causing them to turn over and set the whole of the neighbouring pieces in motion. This is probably the reason why disintegration, when it has once commenced, goes on so rapidly, and even continues for some time after the midday heat is over; for the temperature of the air does not rise above 64° Fahr., and the water of the fiord is too cold to admit of the hand being plunged in it for many minutes without causing acute pain.

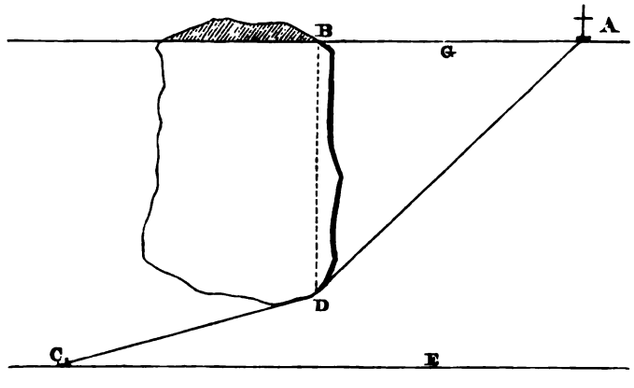
The great depth of the fiords constitutes one of their most striking characteristics. During my attempts to dredge, I rarely met with less than 20 fathoms close to the shore, whilst as the centre of the fiords was approached it ranged from that up to 150 fathoms. At one portion of the large bay stretching across from Hernhutt towards the sea the dredge was let go in 200 fathoms, and from that great depth brought up a number of Sea Urchins (*Echinus Sphæra*).

But the depth was by no means the only obstacle to the use of the dredge. The powerful tide, the quantities of drifting ice, and the nature of the bottom,

which seems to consist almost entirely of boulders, all tended to render it both tedious and hazardous; and on more than one occasion I had cause to be thankful that, during my endeavours to clear the dredging-line from the large masses of ice that continually drifted against and fouled it, their sudden plunging over did not send my small crew and myself on a sounding expedition for which we were but ill prepared.

The following method of computing the ratio of immersion and elevation of floating ice-masses suggested itself to me on one occasion of the line becoming entangled. As I am not aware that any practical plan has heretofore been devised for ascertaining the point, I may perhaps be permitted to illustrate it by a diagram.

Suppose BD to represent a mass of floating ice; G, the water-line; E, the bed of the sea; AC, a grappling iron or deep-sea lead and line, impinging at D against the base of the ice-mass; and A a boat or ship.



Assuming the imaginary line BD to be perpendicular, and that we can measure the distance from A to B, it is obvious that we have two angles DBA and DAB, and a base-line AB, from which we can at once deduce the length of the side BD. But all calculation may be avoided by the simple expedient of moving the boat at A until the angle DAB equals 45°,—the base-line AB being then equal to BD, which represents the immersion of the mass. Lastly, the height of the portion above water being measured with an oar or boat-hook, the ratio may be calculated.

Availing myself of this plan, I found that for every foot above water, in such masses as maintained nearly the same proportions above and below the surface, there was never less than 14 feet below the water-line, and generally as much as 16. As I have already stated, the whole of the ice met with at Goodhaab is precisely similar in appearance and character to that we fell in with at sea, and cannot be regarded as the freshwater ice, which is said to be much more com-

pact and clear in its texture, and to be heavier than the ordinary pack-ice, bulk for bulk,—the difference I have referred to, namely in the ratio between 1 to 14 and 1 to 16, being, I conceive, wholly attributable to accidental differences in the solid contents of the submerged and exposed portions. Thus, in a small berg which was stranded at the head of one of the fiords, I found the ratio of submergence to elevation to be only 7 to 1; but the cause of this decreased ratio was manifest, inasmuch as the portion above water rose up to an angular peak, whereas from the water-line, as deep as the eye could penetrate into the clear water, the berg retained its dimensions. As it was aground close to the shore, I was enabled to measure the height of its summit by scrambling up the hill-side adjoining, and I found it to be a little above 40 feet. The water immediately around it, as measured by a plummet, was somewhat more than 50 fathoms. At the period of the tide at which I inspected it, the line of floatation was 6 feet from the surface of the fiord. But it was parallel to it, and it is therefore unlikely that the berg could have been resting on a boulder or rock elevated above the general level of the bottom. Assuming, then, as the appearances warrant, that the solid contents of the 40 feet above water were equal to half the solid contents of a like number of feet below water, we should have a ratio of 1 to 15, or the mean of that established by actual measurement.

I have alluded to the presence of boulders in the fiords adjoining the anchorage at Goodhaab. From the clearness and stillness of the water, it was often possible to observe the bottom, near the shore-line, at considerable depths; and I was sorely puzzled to account for the smooth rounded look of the greater portion of these stones. It was evident these could not have been subject to the action of waves, from the depth at which they lay. There was no glacier in the vicinity to which their presence and figure might have been attributable. Nor did it seem probable that such a uniform distribution could have been effected by icebergs or ordinary drift-ice which had brought them from distant localities. On examining the character of those occurring near low-water mark, I found it corresponded with the rock-formation of which the surrounding heights was composed. But as the same kind of formation is said to prevail along the greater portion of the west coast of Greenland, both to the north and south, it offered no satisfactory explanation as to the origin of the boulders in the present locality.

At the south-eastern angle of the large fiord to the southward of the anchorage, I found not only that these boulders were congregated together in unusually large quantity, but that they formed a sort of moraine, extending along a valley which ascended for about 2000 feet up the mountain. Following this valley to its crest, I arrived at a tarn of nearly a mile in diameter, occupying an amphitheatre the whole of which, with the exception of the part next to the fiord, was bounded by a precipitous escarpment. The height of this could not have been less than 1000 feet. Its face seemed to be cut up into innumerable channels, as if by the overflow of torrents at its upper margin; but water was only streaming down a few of these, and apparently in no great volume. The margin of the tarn was perfectly level all round, and occupied the entire area of the amphitheatre thus formed. As the water was only about a foot and a half in depth, and its temperature, comparatively speaking, warm from the absence of ice, I waded in for some distance, and found that the bed consisted of nothing but an accumulation of boulders, all more or less perfectly rounded. From the appearance of the valley, the remains in it of enormous boulders of quartz-rock, some of which are 15 feet in diameter, and the polished and, in places, furrowed surfaces of the schistose rock which constitutes the bed of the valley itself, it would seem probable that this had once been occupied by a glacier, and that the masses of rock detached from the escarpment on the melting of the snows are worn down into their present form during their transit across the flat bed of the tarn and ultimately carried along by the torrents to the fiord below. Once arrived there, and deposited in a gradual slope, the ice formed in the winter would bear them away and distribute them over the bottom.

A curious corroboration of the perpetual grinding to which the boulders in the tarn are subject is derived from the fact that not a trace of any of those microscopic algæ, or lower animal forms, with which the surfaces of smooth stones are invariably encrusted, even in streams running with considerable velocity, could be scraped off with a knife; whereas in some small rocky pools situated on the slopes of the lower hills, I met not only with Confervæ, but Diatoms growing in great profusion, and between twenty and thirty species of Desmidiaceæ.

Aug. 13.—From infancy the Esquimaux is taught to regard the sea as his special domain, and to look to it as his great store-house for food, for clothing, and, in short, for everything that is absolutely essential to his existence.

His kayak combines symmetry of shape with extreme lightness and strength: it is formed of seal-skin stretched over a framework made partly of drift pine-wood and partly of whalebone. His hunting and fishing implements are constructed of the same material. Every article of his dress, his tent, the window of his hut, the substance which yields him light and warmth in the long Arctic winter, and, in a great measure, his food are products of the sea. Every particle of wood he uses comes from the same source. We might, therefore, naturally expect to find him an adept in the management of his canoe; but I was certainly unprepared for a feat which some of the Exquimaux performed this morning alongside the ship, where the partial clearing away of the ice had left sufficient space for them to manœuvre. It consisted in turning a complete somersault sideways, kayak and all; the occupant of the kayak swaying his body to and fro laterally, with the arms stretched out so as to poise the paddle in front of the chest, until sufficient momentum was engendered; and then capsizing, as it were, on one side and coming up on the other. One poor blear-eyed old man went through this performance at least a dozen times, receiving as his recompense that greatest of all luxuries to an Esquimaux, a pound or two of ship's biscuit and a little tobacco.

The oomiak, like the kayak, is formed of seal-skin, stretched over a wooden and whalebone framework, but, instead of being contrived to hold only one person, is capable of carrying from twelve to twenty. It varies in length from 25 to 35 feet, and in breadth from 4 to 5 feet, and is invariably rowed by women. As might be supposed, boats formed of material so readily torn or pierced by ice or rock must be somewhat liable to accident whilst traversing the Greenland coasts for several hundred miles, as they constantly do. But the tendency to leakage is provided against in a curious and highly characteristic manner, namely, by constantly keeping at hand several large pieces of seal- or whale-blubber; so that, the moment a rent occurs, a proportionally sized lump of this substance may at once be forced into the aperture. Both owing to its oily nature and its great elasticity, it is perhaps more admirably adapted than any other material that could have been hit upon to effect the required object.

Aug. 15.—The ice having materially diminished in quantity, both in Baal's River and the fiords on this side of it, and our supply of coal having been taken on board, at 8 P.M. yesterday, the 'Bulldog' left the harbour in order to proceed

to sea. She had hardly started, however, when a thick fog rolled down from the heights and compelled her to drop anchor again at the head of the nearest fiord. At an early hour this morning she once more got under way, and, taking the 'Nautilus' in tow until clear of the islands at the entrance of Baal's River, commenced her voyage to the southward.

During the day we passed between some extensive fields of ice, and at times approached close to the coast. But, on arriving abreast of Frederickshaab, it became manifest that our chance of effecting a passage into the harbour was as remote as ever. For the fourth time we found the entrance barred against us; and for the fourth time the 'Bulldog' is ploughing her way out to sea, with a heavy south-westerly gale blowing.

Aug. 16.—The gale abated this morning; and at noon we were steering towards Julianshaab, a Danish settlement about midway between Frederickshaab and Cape Farewell,—Cape Desolation bearing south-east, and distant about a hundred miles.

The surface of the sea was more or less covered by extensive fields of fragmentary ice in the last stage of decay. Some of these fields were two or three miles in diameter,—the close aggregation of the pieces being due, in all probability, to the long rolling swell and calm which have set in since the gale moderated. My attention was arrested by the continuous crackling sound audible on all sides as the ship traversed these ice-fields, and which resembled the pattering of heavy rain-drops when falling on sheets of metal. Being quite unable to account for the peculiar character of the sounds by the mere collision of such small masses—for they rarely exceeded 6 or 8 inches in thickness, whilst the greater number were considerably under that size—I procured a bucketful, and, to my surprise, discovered that they were produced by the ice being in such a state of decay that a very slight blow sufficed to break it up still further, and to explode the minute air-chambers in its substance. Some of the pieces were full of these air-chambers, besides being riddled by tubular cavities exactly resembling the holes bored by *Teredo*, sometimes open at either end, sometimes only at one, but never closed at both. The air-chambers, on the other hand, could be seen distinctly in the substance of the ice as closed cavities, like the little air-bubbles often seen in glass.

I conceive that the rapid disappearance of the pack-ice from the west coast

of Greenland is, in a great measure, attributable to the agency exerted by these cavities in breaking up the masses after the process of thawing or, in other words, ice-decay has proceeded to a certain extent. The growth of ice, as is well known, takes place from above downwards: that is to say, the uppermost layer of a frozen surface is the one which was first generated; the same rule holds good with each subsequently formed layer in relation to those below it again; so that the undermost layer is necessarily the one last produced.

Under the influence of winds and waves, a certain quantity of the atmospheric air with which sea-water is invariably charged is constantly being given off again at the surface. The moment a pellicle of ice forms, it precludes the escape of the air-bubbles, and they become frozen into the ice-mass at a time when, from the reduction in temperature, they are very much reduced in volume.

In the case of icebergs the same result takes place, although in a somewhat different manner. Berg-ice, as is well known, is produced on land, and is, in reality, snow solidified under enormous pressure. Here, then, the case is reversed, the undermost layer being the oldest of the series. Consequently the air entangled in the snow-flakes, also at a time when reduced in volume by cold, becomes more and more compressed, whilst the substance within which it is imprisoned becomes more and more solidified. Now the very cause that brings about the decay of ice, namely, elevation of temperature, produces the expansion of the air contained in the chambers; and thus the expansive force operates precisely at the moment when it has the slightest amount of resistance to overcome. Hence the little detonations, and the disruption of the ice-masses that attends them.

The tubular cavities proceed from the disruption of the air-cells on the under surface of ice-masses, whenever the temperature of the water rises sufficiently to produce thaw. The air-bubble, unable to escape, continues to press upwards, whilst the access of the water to the interior of the chamber gradually eats away the walls. A vertical tube is the result, the upper portion of which is occupied by the now somewhat expanded air-bubble, whilst the lower portion is filled with water. This boring goes on until the water within the tube reaches the level of the surrounding surface, but there it necessarily stops; and we can accordingly account for the uniform honeycomb character so constantly presented on one surface of ice-masses. When, by collision or force of any kind, ice is

broken up in a line parallel to its line of floatation, these tubes sometimes penetrate through and through; and in this state I found nearly the whole of the smaller pieces today.

The occurrence of a great number of these cavities at the base of small pieces of ice must also tend materially to influence their submergence, and cause them to tilt over, should the boring action proceed more rapidly in one direction than another.

I have been induced to dwell on this subject, inasmuch as the extremely rapid disappearance of the ice that besets the coast of Greenland for certain months of the year has been regarded either as wholly inexplicable, or has been attributed to a cause which involves an impossibility, namely, its sinking to the bottom *en masse*. From what took place during the last few days of our stay at Godhaab, coupled with the remarkable condition of the ice just described, there can hardly be a doubt that during a very brief continuance of sunshine the entire dissolution of masses of ice many feet in thickness may occur in this manner. Of course the same kind of decay would destroy a hundred square miles of ice as readily as a hundred square inches.

Towards evening land was in sight, but the weather was too thick to see it plainly. Much snow was, however, visible on the higher ranges; and here and there along the coast, the pack could be discerned hemming it in. Our prospect of reaching Julianshaab tomorrow is, therefore, a poor one.

Aug. 17.—Owing, I suppose, to the powerful north-westerly current, we are still well to the northward of Cape Desolation. Last night the 'Bulldog,' under sail only, and with a light breeze blowing, came in for some heavy bumps, one large mass of ice seeming intent on trying conclusions with the starboard paddle. The damage done was only trifling, however. We are now running down in the direction of Cape Farewell under steam and sail, with the wind right aft. The ice forms a belt commencing about three or four miles from us, and stretches away to the land, which is distant about forty or forty-five miles. Whilst I write, the ship is receiving some heavy concussions.

Aug. 18.—This afternoon Cape Christian was sighted to the north-eastward, —the ice extending along the coast in a vast unbroken field of forty miles in diameter, and apparently increasing in quantity as the stream passes round Cape Farewell. The 'Bulldog' is now quite clear of the pack, and has made

the first sounding between Greenland and the mouth of Hamilton's Inlet, in north lat. 59° 22′ and west long. 45° 54′, the depth indicated being 1177 fathoms.

Aug. 23.—Inclusive of the soundings taken on the 18th inst., the depth has been ascertained fifteen times between Cape Farewell and our position at noon today. With the exception of the last sounding, taken at 9 A.M. in 280 fathoms, the depths have ranged between 1150 and 2032 fathoms, bottom having been brought up four times. In a distance of about seven or eight miles between the 280-fathom sounding and that immediately preceding it, there is a rapid decrease in depth from 1190 to 280 fathoms—being at the rate of about 700 feet per mile, or nearly identical with the dip which occurs off the west coast of Ireland in the mid-Atlantic line.

A sounding made this morning with Brooke's apparatus brought up only two grains of bottom,—a small stone, about half an inch in length by a third in width and thickness, having stuck in the valve and permitted the escape of whatever other material may have occupied the cavity of the cylinder.

Aug. 24.—On approaching Hamilton's Inlet, the coast to the north and south of it presented a singularly unattractive character. Instead of the bold rugged cliff-scenery of Greenland, nothing was to be seen but an unbroken succession of low rounded hills, with scarcely a trace of vegetation on their surfaces. This afternoon we passed the Esquimaux Islands, lying off the entrance to the inlet; and at 6 P.M. the 'Bulldog' anchored at Indian Harbour.

CHAPTER IV.

INDIAN HARBOUR.—COAST-FORMATION.—BLUFF-HEAD COVE.—RIGOLETTE.—THE NARROWS.—NORTH-WEST RIVER.—CLIMATE.—NUMBER OF SETTLERS.—MARL BED.—SPRINGS.—HAMILTON'S RIVER.—CULTIVATION AT NORTH-WEST RIVER.—BOULDERS.—EXTENT OF INLET.—NATURE OF ITS BED.—PROCEED TO SEA.—CAPE BRETON.—RETURN TO INDIAN HARBOUR.—SHOAL.—DEEP-SEA SOUNDINGS.—ICEBERGS.—ARRIVAL AT JULIANSHAAB.

INDIAN HARBOUR is situated in a sheltered channel between the mainland and one of the largest of the group of islands at the mouth of the inlet. An extensive cod-fishery is carried on here during the four summer months. At present it is drawing to a close, and only a few small vessels remain to complete their cargoes. Mr. Norman, a Newfoundland merchant, who comes to reside on the spot during the continuance of the fishery, informs me that the present has been an unusually stormy season, and that the quantity of cod taken has been far short of the average. On the other hand, the quantity of ice met with on the coast has been unusually small, the long prevalence of south-easterly gales having tended to drive the ice close in shore, higher up the coast of Labrador, so as to be beyond the influence of the descending arctic current. He says that although a vast number of bergs drift to the southward or ground in shoal water near the outer islands, they very rarely enter the inlet. Some of the fishermen, however, state that whilst the larger bergs cannot pass inside, moderate-sized ones are to be seen, at times in considerable numbers. But as the place appears to be altogether deserted during winter, in consequence of the severity of the climate, it is somewhat difficult to make out how far these assertions depend on actual observation, and how far on mere supposition or hearsay.

The entire coast seems to be composed of a grey disintegrated granite, in which there is a large preponderance of felspar, with vast basaltic dykes sometimes cutting the islands and hills longitudinally, sometimes constituting the entire mass. An island to the left of the entrance to our present anchorage presents a very remarkable dyke, of the kind referred to, just above and parallel

with high-water line. On another island, one of the loftiest in the neighbourhood, and distant from any other, the highest ridge is occupied by a series of immense boulders. How they attained this extraordinary position I am unable to surmise, our brief stay at Indian Harbour rendering it impossible for me to reach the island.

Although Hamilton's Inlet is in the same latitude as Sligo or Yorkshire, the climate and vegetation are purely sub-arctic, and in the neighbourhood of the sea, at all events, there is nothing approaching to cultivation.

Whilst dredging I found that, at a distance of a quarter of a mile from shore, the depth rarely exceeds 10 or 15 fathoms, and that the bottom is wholly formed of uncovered rock or boulders. The shore-line itself consists of large rounded masses of basalt and granite, which are destitute of organic growths of any kind above extreme low-water mark—owing, no doubt, to the long-continuing action of drift-ice and currents.

The method of catching the fish is somewhat singular, and shows that, with all the appliances of civilization, the white man has been unable to teach the Esquimaux how it may be improved. As carried on here, it is precisely similar to that practised by the kayakers in Greenland,—three hooks being attached to a slipper-shaped sinker, about 5 inches in length, which is "jigged" up and down as the boat drifts along. No bait whatever is used.

With a view to obtain some information regarding the depths of water and nature of bottom at this part of the inlet, I went alongside one or two of the boats. Although the men were catching fish as fast as they could let down their lines, they all corroborated the statement of Mr. Norman regarding the poorness of the fishery this year. Failing to elicit any facts bearing on the zoology of the bottom from the fishermen, it struck me it might be derived from the fish themselves. Accordingly I purchased forty, varying in weight from two to ten pounds, for the small sum of four shillings. On appealing to the stomachs of a few of these, I was equally unfortunate; for, with one exception, they were entirely empty. They appear to be hooked almost as often by the body as by the jaws, and in two out of the forty fish I had purchased there were distinct cicatrices showing where they had been hooked on a previous occasion. As all fish under a certain weight are thrown into the water again, those that survive their injuries would present similar marks.

Aug. 25.—Anchored in the evening at Bluff-Head Cove, about twenty miles up the inlet. The naked character of the shores is already replaced by a growth of dwarf spruce-fir, from one to three feet in height. The only resident in this lonely spot is a Dorsetshire man. He states that the inlet is completely frozen over in winter, and that his hunting-journeys are then made by sledge. His dogs are a breed between the true Esquimaux and the native Labrador dog. They are very handsome, and sociable to a degree that proves canine distrust to be engendered by man's presence rather than his absence. One of the dogs had lost a fore leg in an encounter with a bear, but seemed hardly to feel the loss of his limb. He was the leading dog of the team before the accident, and retains his post of honour still,—the absent member being replaced by a hide bag stuffed tightly with moss, and secured around the stump. Thus equipped, the poor animal performs his work, and frequently traverses from thirty to forty miles a day.

The soundings taken from Indian Harbour up to this point are composed of granitic sand, containing scarcely a trace of organic matter, either animal or vegetable. The almost entire absence of any of the ordinary sea-birds was very remarkable at the mouth of the inlet. The condition of the rocks indicated that none frequented them. As we ascend further up the inlet, a few Ravens, Sea-parrots, and Dovekies show themselves; but otherwise there is no living creature to be seen above water.

Aug. 27.—Early this morning the 'Bulldog' steamed up the inlet, taking bearings and soundings along her course. The hills on either side already become somewhat loftier and more wooded; but the spruce-firs seem only to thrive at a sufficient elevation above the shore-line to be beyond the influence of the salt-water spray, and are still of too stunted a growth to detract materially from the bare and unvaried character of the scenery.

Towards sunset several whales of small size were seen cruising about, but at too great a distance to enable us to make out the species. The pilot we took on board lower down the inlet states that no attempt has ever been made to capture these animals. About the same time immense flights of Puffins kept crossing over from the southern towards the northern shore, where, for some distance, the land appears to be flat and marshy; and it was very curious to watch the Dovekies rising up to the previously unruffled surface of the water as the ship approached,

scared to such a degree that for some moments they appeared unable to make up their minds from which of the two elements around them they might expect the greatest security. Owing to the calmness of the surface, it was possible to see a long way ahead; and although here and there a bird might bob up, there was nothing like the consentaneous uprising just referred to. The fact is worthy of record, because, although the powers of the Divers and Auks to remain under water for considerable periods are well known, it would almost appear that these little auks live as much below water as above it, and continue gregarious whilst diving.

This is the first bright moonlight night we have had since we put to sea. There is not a cloud in the sky; and the deep silence is broken only by the murmur of the tide against the sides of the ship. How different from a similar night-scene in the tropics, where a hundred strange noises, produced by night-roaming beasts, birds, and insects, would strike the ear, and impart to it a charm, the more intense the more unfrequented and wild the locality.

Aug. 28.—At 8 A.M. we arrived at Rigolette, a very picturesque little station belonging to the Hudson's Bay Company, occupied at present by a couple of their *employés*. It is situated in an extensive reach, bounded by granitic hills, clothed with spruce-fir and white birch. The salmon-fishery is carried on here on a large scale, but, as already mentioned, is just over for the season. It appears that two large decked boats which passed us yesterday afternoon were conveying the salmon, and also the furs collected, to Indian Harbour, where they are shipped for their destination by the Company's Agent.

The mosquitos are more numerous, more venomous, and larger than any I have ever seen elsewhere. No precaution short of tying the head up in a gauze bag suffices to protect it from their attacks; and my gauze nets were accordingly in great requisition. Wherever the skin is exposed for a moment, a dozen mosquitos immediately settle and draw large drops of blood. Their bloodthirstiness is only equalled by their stupidity; for whilst an Indian mosquito appears instinctively to know from the gesture of his victim when any attempt is about to be made to destroy him, and instantly retreats, these Labrador mosquitos go on sucking their fill, and stolidly await the blow which terminates their existence.

I endeavoured to make my way through the pine-forest to a freshwater lake

said to be distant a mile from Rigolette; but after walking for a mile and a half through a swampy sphagnum-covered clearing to the summit of a plateau commanding a view of the lake, I saw that at least a couple of miles still remained to be traversed, and accordingly returned in order to be back in time for the departure of the ship.

The heat today was quite oppressive. In some mountains visible to the westward, snow covers the summits. The Hudson's Bay officials inform me that the winter at this part of the inlet is by no means severe, althongh the temperature often falls as low as —30° Fahr.

Some miles above Rigolette the stream suddenly contracts, and, sweeping round a bluff island that rises up in the centre of its channel, rushes with great velocity through "The Narrows." At certain periods of the year the current at this portion of the inlet is said to attain a speed of from seven to eight miles an hour, and to prevent the formation of ice when the rest of the inlet is frozen over to the thickness of several feet. Not far from this point, a considerable branch is given off from the southern shore, which is said to extend in an easterly direction about fifty miles, but without forming any communication with the sea. This branch is called "Back River."

On emerging from "The Narrows," we entered a large expanse of water stretching away to the westward as far as the eye could reach, and apparently about twelve or fifteen miles in breadth. When we anchored for the night, there was still no land visible above the water-line to the westward*.

The higher we advance up this magnificent arm of the sea, the greater is the distance reported to be between its eastern and western boundaries. At Indian Harbour we were informed that the extreme length was between ninety and a hundred miles. Today, at Rigolette, it is stated to be nearly 120. I mention the circumstance because, although it is by no means to be wondered at, that persons moving about from settlement to settlement should only possess a general knowledge of the geography of the country, one would certainly expect to find the bearings of such an inlet as this correctly laid down in the most modern maps, and it seems almost incredible that, within a few hundred miles of our North American colonies and naval stations, an arm of the sea of sufficient

* This extensive tract of water is noted in some charts as "Melville Lake;" but none of the settlers along the inlet know it by that name. The Esquimaux name of Hamilton's Inlet is Ivuktok.

extent to shelter the largest fleet in the world, possessing very extensive salmon-, cod-, and capelin-fisheries, the shores of whose tributaries are said to abound in timber of large size which might be floated down in rafts and shipped in deep water, and whose mineral resources are probably neglected solely because they have been undeveloped, should have remained up to the present day so partially explored.

Aug. 29.—Arrived at North-west River, the head of Hamilton's Inlet, and the principal settlement of the Hudson's Bay Company in this part of Labrador. Towards the upper extremity of the inlet, the shores converge somewhat, and become gradually flatter and more closely wooded. At this point the channel receives the waters of "North-west" and "Hamilton's" Rivers. The former, or more northerly branch as its name implies, debouches into the inlet by a narrow channel only about eighty yards in width—the settlement being on the northern shore, and situated on a small tract of flat land from which the forest has been cleared. The opposite shore is low, and densely wooded to the water's edge, but none of the trees are above 30 or 35 feet in height.

Mr. Smith, the superintendent of the district, who has resided here for many years, speaks in high terms of the healthiness of the climate, notwithstanding the great alternations of temperature. He has known the thermometer in the month of July to stand at 110° in the shade, and to range at night up to 90°. But the last was an exceptional case. During the continuance of these extreme heats, the mosquitos, with which the inlet swarms to a degree unknown save in some parts of tropical America, vanished completely. Winter commences in November. The chief fall of snow occurs in January, the temperature then ranging from −5° to −50°. In 1856 it fell to −54°. Heavy gales occur in October. Last year two terrific hurricanes took place, on the 8th and 26th of October. The first continued for two days, and blew from the north-westward. The second lasted only for a few hours, but was by far the most severe. It blew from the eastward. If I am not much mistaken, it was on or about the latter date that the 'Royal Charter' was wrecked on our own shores. Rain falls very rarely except in August and September; but the fall is then very heavy and continuous. Mr. Smith states that the men complain more of the severe effects of the sun in spring, which blisters their faces and affects their eyes, than of the intense cold. They seldom wear furs, even in the depth of winter—their

clothing consisting of stout woollen undergarments with blanket coats and trousers, and mocassins made of deer-skin. When out in the winter, the hunter carries no tent, but only a couple of blankets, his gun, and his knife.

The skins brought to the settlement both by the Canadian and Indian hunters consist of the white and black bear, reindeer, a species of lynx, ermine, mink, sable, wolverine, and the white and black fox. The black fox-skin is by far the most valuable and the rarest. Only four were procured last year. Their value ranges from £10 to £15 on the spot, but in Europe they readily fetch from £30 to £40. It appears that they are not in such request for the European markets as for the Chinese. The skins are first purchased by merchants in England. From thence they are sent to the great annual fair at Leipsic, and ultimately find their way to China, where they are greatly sought after by the mandarins. The skin of the carabboo* is brought in from the interior by the Red Indians, but always in a tanned state.

All skins procured by the hunters are taken at a contract price by the Hudson's Bay Company's agent, the proceeds being divided equally amongst the men of the party to which the captor belongs. The advantages of this mode of reward are twofold, inasmuch as it stimulates every man to work energetically, and induces each party of men to coerce such as are inclined to be idle.

Salmon and salmon-trout are taken in great quantity throughout the entire length of Hamilton's Inlet and the rivers that flow into it. Mr. Smith states that the pike also occurs, and a species of shark about 4 feet in length, quite distinct from the dog-fish. I was unable to procure specimens, however. Capelins and cod-fish are only taken near the mouth of the inlet and along the coast.

The total number of settlers on the shores of Hamilton's Inlet, including those of mixed descent, is computed at 200. Although no new colonists come out, the settlers are gradually on the increase. On the other hand, the Esquimaux, who formerly were plentiful towards the lower portion of the inlet, are slowly dying out. Some years ago a great number were carried off in a very brief period by some virulent contagious disease. Their skeletons are still strewed over the surface of an island, not far from the one mentioned as occurring near "The Narrows," which retains the name of Esquimaux Island in consequence.

* This is believed to be a large variety of the Reindeer (*C. Tarandus*); but, from the description Mr. Smith gave of it, it would almost appear that a distinct species was referred to.

We found a party of American Indians, belonging to the Cree tribe, encamped on the shore a little way from the settlement. The main body had left only a day or two before. They had come down from the interior to barter skins for articles of English manufacture and food, such as blankets, cloth, hardware, and biscuit. The value of all these is regulated by a tariff with which they have become familiar; for no money transactions are carried on. In like manner there is a fixed value imposed on all kinds of skins.

It is a curious fact that the Indians will, on no account, bring in the entire body of the carabboo deer, or indeed any portion but the skin. There is a superstition current amongst them, that whoever brings one of these to the white man will meet with dire misfortune, and that his hunting-grounds will be destroyed. Mr. Smith informed me that although large bribes have been offered for specimens, they have proved unavailing, the Indians declining to bring in even the head or horns. He added that he had no doubt that, were he to order an Indian hunter to bring in a carabboo, the order would be obeyed; but any subsequent mishap or loss would at once be referred to his agency, and the trade might thereby be very seriously injured. The Indians subsist in a great measure on the flesh of the carabboo; but they leave the bones and other remains on the spot where they cut it up, and invariably tan the skin before bringing it to the settlement.

Hearing that a bed of marl and shells occurs some way up North-west River, I proceeded to the spot in an Indian birch-bark canoe. About 200 yards above the settlement the North-west River spreads out into a large nearly circular sheet of water, about three miles in diameter. A narrow channel, similar to the one opposite the settlement, but of greater length and fringed with the densest pine-forest, succeeds this, and opens out into another large expanse of water, called "Grand Lake." This is about three miles in width, and is said to extend westwards for forty miles, where it terminates in a small river amongst the mountains. At each of the narrows there are rapids, but not of sufficient velocity to prevent a boat being rowed up close along the shores. At the spot indicated, I found a disintegrated calcareous marl, wholly made up of minute friable portions of a Mytilus-shell. The underlying strata were not visible, as the shore was densely wooded down to the water's edge, and the underwood had only been cleared away where the marl had been dug. The frag-

ments of shell have the fibrous aspect of asbestos, but crumble with the slightest touch. The deposit must have been derived from salt water at a period when this portion of the inlet was considerably lower than it is at present, and thus subject to the constant influx of salt water. There are no marine mollusca found now within many miles of the head of the inlet. In the water immediately adjoining the marl-bed, and down as far as the settlement, Limnæas occurred in great abundance, adherent to stones. The water above the settlement is perfectly fresh, as might be anticipated from the strength of the current. At our anchorage the hydrometer indicated nearly pure fresh water. And yet the tide influences the inlet at this distance from the sea, namely, 120 miles. In winter, I am informed, the amount of saline admixture, in the vicinity of the anchorage, becomes very perceptible. On inquiring whether freshwater springs occur along the shores, my boatmen mentioned that a remarkable spring was to be met with about half a mile higher up. On paddling to it, I was much astonished to see one large and several smaller geyser-like orifices at the sandy bottom of the river, where the depth was about a foot and a half. Their orifices were well defined, and could readily be examined, from the perfect clearness of the water. The orifice of the largest was 6 inches in diameter, quite circular, and surrounded by a cone-shaped crater of sand. Through this the water spouted with sufficient force to cause the jet to rise to a considerable elevation above the surface of the stream. The temperature was at least ten degrees below that of the river-water, and therefore leads to the inference that these springs take their origin in some of the more distant and elevated mountain-ranges. There are seven smaller springs, with apertures varying in diameter from 1 to 3 inches. The whole are distributed over an area of about 8 yards square,—the bottom of the river in their vicinity, and even the gravel-covered shore, which, to all appearance is perfectly firm, affording a most treacherous and somewhat dangerous footing.

It is currently believed here that some stupendous waterfalls occur at a distance of about 200 miles up Hamilton's River. The Indian hunters are well aware of the existence of these falls, but speak of them with such a degree of superstitious awe as to account for their admission of never having approached within sight of them. They concur in the statement that at twenty miles distance the roar of the cataract is terrific, and that, on coming within three miles, the vibration of the ground is so great as to give the impression of sub-

terranean action immediately underground. It appears, however, that some years ago Mr. Maclean, a gentleman in the service of the Hudson's Bay Company, whilst endeavouring to reach the east coast of Labrador from the westward, inspected these falls. In an account published by him of his journey*, Mr. Maclean states that, at a distance of six miles above the cataract, the stream contracts in width from 600 to about 100 yards, and, after rushing along in a continuous foaming rapid, finally contracts to a breadth of about 50 yards, when it precipitates itself over the rock which forms the fall. It now continues its course, pent up in a precipitous zigzag gorge, for thirty miles—the walls of rock sometimes rising to a height of 300 feet on either side, and concealing the torrent from view till the chasm is reached. The formation is said to be syenitic.

At North-west River, oats, barley, potatoes, cabbages, turnips, and rhubarb have become articles of regular produce, but as yet only in limited quantity—the scanty nature of the surface-soil, which is characteristic of the shores of this inlet, rendering cultivation of all kinds difficult, notwithstanding the high temperature during the summer months, and the great facilities of irrigation. Hay-making is now going on, the thermometer standing, in the shade, this afternoon, at 84° Fahr.

Aug. 30.—Leaving North-west River at an early hour this morning, the 'Bulldog' commenced her return voyage down the inlet, and at noon anchored off the bluff headland known as "Long Point," in order to survey.

The hills in the vicinity of this headland are entirely composed of a grey finely striated labradorite, traversed by narrow dykes of dense black basalt. At North-west River, wherever the rock formation cropped out, the same kind of labradorite was to be seen. The shore is here covered with a succession of large rounded boulders of felspathic, and also hypogene rocks not to be met with in the immediate neighbourhood. Some of these were as much as 3 feet in diameter, and indicate that the drift-ice, by which it is probable they were transported to their present position, must have been of very considerable thickness. At North-west River I learned that in ordinary seasons the ice on the inlet attains a thickness of three feet. At Chator Island, on which I landed on the 27th inst., I saw some boulders of quartzose rock, at least 5 feet in diameter.

* 'Notes of a Twenty-five years' Service on the Hudson's Bay Territory.' By J. Maclean. London, 1849.

Wherever I landed along the shores of the mainland, there was a thick-matted layer of sphagnum and lichen growth. At "Long Point" this was almost completely obscured here and there, where the forest did not extend, by a network of red and black whortleberry, wild yellow raspberry, and, on the more rocky surfaces, common juniper and crowberry. The fruit of the first of these was so plentiful that it could be shaken off in handfuls. Both bears and ptarmigan, which abound in the neighbourhood, feed on it almost exclusively. Lower down the inlet the wild fetid currant was met with.

The 'Bulldog' proceeded on her course at 3 P.M., and, after encountering a very powerful current whilst rounding a headland abreast of Esquimaux Island, anchored for the night in Esquimaux Harbour. This current was an ascending one, due to the flood tide.

The length of Hamilton's Inlet, from Indian Harbour to North-west River, is 118 miles. At its mouth the width is nearly fifteen miles, the deepest water at this part being about the central portion of the five miles intervening between George Island and the northern shore. The bottom, as brought up by the sounding-machine along the navigable channel, consists of detritus of granitic, basaltic, and felspathic rock, with an extremely small sprinkling, as far up as "Bluff Head Cove," of the lower animal and vegetable forms. From that point up to North-west River, it consists of a coarse felspathic and quartzose sand, without any organic structures whatever. Near the sea the bottom is coarsely muddy; but the finer particles gradually disappear, and at the head of the inlet the quantity of mud is inappreciable, the bottom consisting entirely of clear sand. Wherever I dredged near the anchorages in shallow water fringing the shore, I found *Algæ*, *Confervæ*, and the more minute forms of animal and vegetable life abundantly represented, and large quantities of fine mud. The very marked paucity, and in some places total absence, of minute organic forms, fine mud, or débris of the larger organisms, clearly points to the current being of sufficient velocity to wash out the central channel, as it were, and convey the particles thus acquired far out to sea.

Sept. 16.—On the 31st ult. the 'Bulldog,' having completed the survey of Hamilton's Inlet, proceeded to sea and sounded, in a north-easterly direction, as high as lat. 56° 2′ N., long. 54° 3′ W. The course was now altered, and, steering to the southward, she passed through the Straits of Belle Isle on the 3rd inst., and

arrived on the morning of the 6th at Sydney Harbour, Cape Breton. Having completed coaling, the ship started on her return voyage on the 12th inst., and, taking an inner line of soundings, commencing in lat. 52° 44′ N. parallel with the south-eastern coast of Labrador, this evening once more came to anchor at Indian Harbour.

Leaving Indian Harbour on the 17th September, soundings were taken from the entrance of the inlet, in a northerly direction, along the 57th degree of latitude, as far as 55° 33′ N. At this point a sudden increase of depth occurs, from 148 to 950 fathoms in a distance of seven miles; being at the rate of 687 feet per mile, or somewhat less than the Valencia dip. These several lines of soundings prove that a shoal extends north and south of Hamilton's Inlet for three degrees of latitude, and for a distance of at least a hundred miles in an easterly direction from its entrance. Hence this shoal would appear to be a continuation of the one referred to by Sir J. C. Ross* as occurring off Labrador, in lat. 57° 30′ N., and stated by that distinguished arctic navigator to stretch parallel with the coast for a considerable distance both north and south of the latitude of Okak, a Moravian settlement to the southward of Cape Mugford. Sir James Ross mentions that the depth of water in that neighbourhood is 60 fathoms, and that the shoal is marked by the line of icebergs which were grounded on it on both the occasions on which he crossed it. In approaching the coast and in our passage outwards from it, icebergs were seen, but not in any great numbers. To the southward of Labrador, the soundings, both as regards depth of water and nature of bottom, would seem to indicate that this shoal is continuous with the great bank of Newfoundland; and whilst the material that forms it northward of the 53rd degree of latitude is derived from the vast outpourings of Hamilton's Inlet and the rivers that flow into its western extremity, the more southerly portion, namely, that which extends from the 53rd degree of latitude to the most southern limit of the Newfoundland shoal, is derived partly from the same source and partly from the outpourings of the Gulf of St. Lawrence.

But although, as I have already stated, there is every reason to believe the shoal referred to by Sir James Ross, as stretching north and south of latitude 57° 30′ N., is continuous with the shoal determined by the 'Bulldog' soundings, inasmuch as there is nothing known of the coast-formation or the course of

* 'Parliamentary Report to inquire into the Construction of Telegraph-Cables,' p. 188, 1861.

the arctic drift which could suggest the probability of an intermediate deep channel, it must be borne in mind that the depth between lat. 55° 30′ N. and 57° 10′ N. (that is, allowing the southward extension from the latitude of Okak as determined by Sir J. Ross's evidence) remains to be ascertained, and that a deep channel *may* exist in this interval. But as the two deep soundings recorded by the 'Bulldog' occur near the 57th degree of latitude, and the coast-line falls back to the north-westward, in the direction of Okak, it is probable that the shoal-water margin ranges in a similar direction, and, accordingly, that the two soundings in 950 and 1190 fathoms were to the eastward of it.

Sept. 29.—Julianshaab. A continuance of bad weather and several heavy gales have protracted to thirteen days a voyage which could easily have been performed in two; and hence the 'Bulldog' only succeeded in reaching Julianshaab this evening. Since we deviated, on the 17th inst., from the shoal in the 57th degree of west longitude, three soundings have been taken—the first in 1938 fathoms, the second in 2000 fathoms, and the third in 1912 fathoms, bottom being brought up twice.

Yesterday, during a severe gale, a swallow (*Hirundo rufus*) was blown on board and caught. From the direction of the wind, it is probable that the bird must have come from the Labrador coast, the nearest point of which is distant 540 miles. On being brought down to the ward-room, it seemed to relish the warmth and rest, and did not hesitate to perch on the finger held out to it. Under the influence of extreme cold, fatigue, and hunger, all instinctive fear seemed to be eclipsed; and on being left alone after a while, the poor little animal ensconced itself under the globe of a lighted moderator-lamp. Putting its head beneath its wing, it soon fell asleep, dreaming perhaps of green fields and summer skies it was never more destined to enjoy on this side the Styx.

Today we passed through a vast quantity of drift and berg-ice, and, at a distance of about thirty miles from the coast, fell in with a much larger number of bergs than we had previously seen congregated together. At one time I counted upwards of eighty, many of which were of very large dimensions. Owing to the sea being so thickly covered, the water was perfectly calm, and the 'Bulldog' threaded her way through the icy labyrinth with perfect ease and safety. About sunset we made the long rocky spit which bounds the southern angle of the entrance to Julianshaab Fiord, and in an hour more reached the anchorage.

CHAPTER V.

JULIANSHAAB.—SEVERITY OF SEASON.—OLD SCANDINAVIAN RUINS.—SCENERY OF FIORD.—DEPARTURE FROM JULIANSHAAB.—ICE.—GALES.—BESET.—ESCAPE FROM PACK.—TERRIFIC HURRICANE.—UGLY BERG.—BOULDER AND DETRITUS-LADEN BERGS.—CAUSES OF THEIR RARITY.—THEIR FREQUENCY IN HIGH ARCTIC LATITUDES.—INERTIA OF MASSES OF PACK-ICE.—TALLERT BANK A MODERN DRIFT-BED.—SUBGLACIAL VALLEYS.—THEIR MODE OF FORMATION.—CAVERN-REMAINS.—EFFECTS OF TILTING OF BERGS.—SOUNDINGS.—SUBMERGED LAND.—A MESSAGE FROM THE DEEP SEA-BED.—"THE GRENADIER'S CAP."—REKIAVIK.—CLOSE OF THE CRUISE.

Oct. 1.—Julianshaab is situated in lat. 60° 43′ north, long. 46° 1′ west, at the head of a small sheltered bay which branches off from the Igaliko, or, as it is sometimes called, the Julianshaab Fiord. It is one of the most important settlements on the south coast, and constitutes the dépôt whence the oil and furs collected in the adjacent district are annually shipped for Copenhagen.

Although but a month and a half have elapsed since the expedition left Goodhaab for Labrador, the change in the temperature of the air and the general aspect of the country is very marked. Already snow falls daily, and the surface of the fiords is covered every morning with a thin layer of ice. The Danish residents fully corroborate the statements made at Goodhaab regarding the almost unprecedented severity of the season, and contrast it with the equally unprecedented mildness of the last. They inform me that, although during average seasons the belt of drift-ice effectually bars the ingress of vessels approaching from the sea until the middle of July or beginning of August, there is generally sufficient clear water close in shore to admit of communication by boat between the various settlements along the coast. This year such communication has been almost wholly suspended, and, up to the present date, the Danish vessel which usually arrives with the annual supplies for the colony about the period mentioned is still due.

A peculiar interest attaches to this portion of Greenland from the presence of some old Scandinavian ruins which are supposed to be those of the "East Bygd." Those at the upper extremity of the Igaliko Fiord are the most extensive, and,

according to a current tradition, mark the spot where the last remnant of the adventurous Norsemen who colonized the country between the 9th and 14th centuries were treacherously massacred by the Skrælings.

Oct. 2.—Today I accompanied Sir Leopold M'Clintock in a boat-expedition to examine the ruins, about fourteen miles distant, at the head of the fiord. The weather could hardly have been more unpropitious, inasmuch as snow fell without intermission, and both in going and returning we had to make way against strong head winds. This circumstance, no doubt, imparted a more sombre character to the fiord than it would otherwise have exhibited; yet I doubt whether, under the most favourable conditions as to season and weather, a scene in which there is such an absence of variety, and such vast proportions are associated with desolation so palpable, could be viewed without engendering a sense of profound gloom. This remark applies, however, only to the portions of the fiord between the settlement and its eastern terminus. In the vicinity of the ruins the scenery appeared beautiful, notwithstanding the disadvantages under which it was seen. There the channel, instead of being overshadowed on one side or the other by stupendous precipices, inaccessible save to the sea-gull, spreads out into a broad lake-like expanse, with a gently sloping shore stretching back for nearly half a mile from the water's edge, and then terminating at the base of the mountain-range which protects it to the north-eastward. On this slope the ruins alluded to are situated *.

Oct. 6.—At daybreak on the morning of the 3rd the 'Bulldog' left Julianshaab, and slowly made her way through a dense body of ice which had drifted up with the westerly wind since the previous afternoon and nearly closed the channel. On getting out to sea the quantity of ice, both berg and pack, was found to be much greater than it had been at any previous period since we reached the coast; and in forcing a passage into clear water the ship received a number of very severe collisions. In one of these, which made every timber vibrate from stem to stern, a large piece of the cutwater, about 2 feet square, was carried away. The paddle-floats, as might be expected, also met with

* For a detailed account of these ruins, and information regarding the East and West Bygds, the reader is referred to Captain Graah's 'Narrative of an Expedition to the East Coast of Greenland,' and the 'Historical Monuments of Greenland,' published by the Royal Society of Northern Antiquaries.

serious injuries. At 6 P.M. the ship emerged from the edge of the pack; but shortly afterwards she was again suddenly beset, and it became necessary to lie to for the night. During the latter portion of the night it blew hard, and snow began to fall in great quantity. Yesterday morning the decks and rigging were covered with a deep layer of snow and ice, which rapidly accumulated although removed at short intervals. The masses of pack-ice were of immense size, some of them rising out of the water nearly on a level with the bulwarks, and measuring from 50 to 60 yards in diameter. During the greater part of the morning snow fell so thickly as to obscure objects at twenty yards distance, and all attempts at clearing the ice were fruitless till about noon, when the ship once more found herself in open water.

Oct. 10.—During the whole of the 7th and 8th we experienced heavy gales off Cape Farewell. On the afternoon of the last-named date, the 'Bulldog' approached within five or six miles of the coast, in the vicinity of Prince Christian Sound, without meeting with any ice-pack. The mountain-ranges at this point seem to extend down to the sea, forming a series of lofty and precipitous escarpments, with intervening fiords and outlying islands. A sounding, taken at the above distance from the coast, showed the depth to be 94 fathoms. A second sounding, taken in the evening, at thirty miles distance, gave 205 fathoms. As night closed in, the gale steadily increased in violence, and, the wind having veered round from north to north-east, whilst our position was still far too close to the southern portion of Greenland to be safe from the dangers of a lee shore, things certainly looked far from promising. From an early hour yesterday morning it blew a terrific hurricane. Not a man in the gallant ship's crew, from the commander downwards, had ever encountered one more severe. To describe it is impossible; for sea and sky were alike obscured by the sheet of seething foam, within which they met in a deadly struggle for mastery. Every moment gigantic waves swept over the ship, as if bent on engulfing her. Everything hoisted in the shape of canvas was blown to tatters. Even the massive engines of the 'Bulldog' were utterly powerless against such a turmoil. Boats, bulwarks, paddle-boxes, bowsprit, and jib-boom, sponson-flooring—the latter formed of 9-inch beams—and tiller-head were more or less shattered to pieces or altogether carried away. The ship laboured terribly, her immense timbers and bulkheads working as if they were going to open outright. Only one sound was to be

heard; and that was the rush of waters and the mad howl of the tempest. It was indeed a sublime sight, and well worth witnessing; but, as there is little fear of such a scene fading from the memory, I candidly confess, to see it once in a lifetime is sufficient for all purposes.

Towards evening the rough edge appeared to have been taken off the gale; but nevertheless it continued during the night to blow furiously. This morning the glass has risen a trifle, and the storm moderated, but there is still plenty of room for improvement.

Oct. 11.—Another hand at the bellows, and from an opposite quarter. During the night the gale continued much as before. The rain which fell had taken the sea down somewhat. But after 11 P.M. the glass again fell, and it was evident the partial lull was only intended as a prelude to a renewed outburst. By 8 A.M. today it commenced to blow fiercely from the westward; and although the recent north-easterly hurricane had still left a tremendous swell, this was rapidly overcome, and succeeded by another from the opposite point of the compass.

About an hour ago the engines had to be disconnected, in order, I believe, to effect some repair; and no sooner had this operation been performed than we found ourselves within a short distance of a large iceberg. The ship's head refused to "pay off;" that is, the effect of the wind on her broadside and immense paddle-boxes was so great in proportion to the power of such sail as it was possible to set, that it occupied nearly half an hour to get her head round, and thus gain the leeward side of the only really ugly berg I have seen since we came to Greenland.

At a rough estimate, I should say the berg must have been about 80 feet in height above the main sea-level, and 100 feet in length. Against this mass of ice the mightiest waves hurled headlong without producing the faintest trace of oscillation; whilst in an instant afterwards they might be seen borne away to leeward, 100 feet at least higher than its summit, as scattered mists annihilated by their own wild vehemence.

It is remarkable that, amongst the numerous icebergs met with in deep water since our first arrival on the Greenland coast, I have only observed seventeen that have presented distinct traces of gravel, stones, or detritus from the bottom. For a time I was perplexed how to account for this, inasmuch as in higher lati-

tudes examples of the kind are known to be frequent. But the comparatively small number of bergs which afforded evidence of their having been reversed or tilted over on their sides suggests an explanation, namely, that so long as icebergs are afloat, the great preponderance in bulk of the submerged portion in the generality of cases renders the effects of wasting above water, or the force exercised by winds and waves even when at a maximum, powerless in disturbing their centres of gravity. Although soundings taken both on the east and west coasts of Greenland clearly indicate that, for distances varying from five to thirty miles from the shore-line, the depth is sufficiently moderate to admit of the grounding of the larger bergs, there cannot be a doubt that the percentage of bergs thus arrested in their transit is so trifling in comparison with those that drift up to the head of Baffin's Bay as to render the cases exceptional. Again, those cases are still more exceptional in which, when large bergs take the ground, they are subjected to impact of bergs equalling or nearly equalling them in dimensions. In the first place, the number, although very great in this part of the ocean, is insignificant in relation to the area over which they are distributed; and in the second, the very nature of the current by which they are borne onwards renders such an occurrence extremely rare, since disparity in the rates of progression of different bergs can only result from disparity in their masses and consequent extent of immersion. In other words, the smaller the berg, the more rapidly would it drift; and hence in the event of a berg overtaking another, and coming into collision with it, the one most likely to be overturned or crushed would be the smaller, and not the larger of the two.

In the event of a continuous field of pack-ice being drifted against stranded bergs, the accumulative force would suffice to overturn or even crush the largest met with in these latitudes. Such an event, in all probability, occurred in the case of the grounded berg alluded to by me as having been seen on the evening of the 31st of July; and I therefore doubly regret that an untoward accident of weather prevented us from witnessing a collision the effects of which must have been so stupendous. Although I was unable to obtain information with regard to the characters of the bergs met with beyond the immediate coast-line from our Danish friends at Goodhaab and Julianshaab, the opinion I have expressed, regarding the extreme rarity of examples in which drift or detritus is observable, is fully borne out by Mr. Tayler, an English gentleman who has resided in

South Greenland for seven years, and has had many opportunities of arriving at a correct knowledge on the subject. He has informed me that not one berg in a thousand of those which drift along the coast presents the appearances in question. To this statement I would append the inference I draw from it, namely, that not one berg in a thousand of those met with below the 64th degree of latitude on the western side of Greenland comes under the influence of those forces which are necessary to alter its centre of gravity to any material extent. I am far from asserting that, where boulders or detritus occur, the surface occupied by them necessarily represents the original base of the mass before it was projected from its parent glacier; but, judging from the appearance of the greater number of large bergs, I think it may be accepted as true that the direction of their upper and under surfaces has not been altered since they constituted part and parcel of the glacier, and that the presence of foreign matters, such as stones and gravel, in most cases is due to their having grounded after being detached, and floating away again only when reduced sufficiently in bulk, by the temperature present, both above and below water. It is also well known that bergs may receive deposits or even boulders whilst afloat by coming into contact with overhanging rock-surfaces; but these examples are obviously too exceptional and rare to affect the present question.

I have already noticed how constantly the submerged portion of bergs spreads in a lateral direction, thereby augmenting the firmness of their bases; and coupling all these facts together, I think it becomes evident we must look for the force capable of coping with masses of matter of such immense volume in that crowding together of bergs which only takes place in higher latitudes, precisely in the same manner that the masses of ordinary pack-ice are crushed and turned over in every possible way by masses of equal proportions with themselves when closely pressed together in drifting fields. In the case of a berg drifting along in shoal water, this extraordinary force is not necessary to produce the result, inasmuch as the momentum of the mass itself, or the leverage exercised by winds or currents, would suffice to tilt it over on its becoming stranded. There is ample proof of this process taking place, inasmuch as in shallow water bergs may frequently be seen laden with gravel or detritus, and exhibiting distinct evidence of having been reversed or tilted over. On the other hand, nothing can demonstrate more conclusively the insignificance of the

forces in operation above water as compared with these ice-masses, so long as they continue afloat, than the majestic immobility of the berg seen on the 11th of October during the continuance of one of the severest gales we have encountered in these waters.

In illustration of the enormous force requisite to move a mass of pack-ice even of moderate dimensions, I would mention that on one occasion, in the vicinity of Frederickshaab, the port paddle came into collision with a piece the superficial diameter of which was about 70 or 80 feet, whilst its average height above water was about 3½ feet, and that, instead of the ship causing the mass of ice to oscillate, the paddle actually mounted on the ice-surface, and caused the ship to heel over until it again became disengaged.

The solitary instance in which I observed evidence of large masses of rock or boulder having been impacted in a berg also occurred during one of our attempts to approach Frederickshaab. This berg was probably about 120 feet in height, and from 300 to 400 feet in length. About 20 feet above the water-line two large cavern-like apertures existed, the inner surfaces of which retained the mud and detritus left behind on the disengagement of the boulders that originally occupied them. Several small stones still remained imbedded; and around them were to be seen smaller cavities, precisely resembling the two first described. Indeed, I should never have suspected that boulders had lodged in the larger cavities, but for the similarity in character between them and the smaller empty ones. I infer that the larger could not have materially increased in diameter by the process of thawing or wave-washing, solely from the presence of the detritus, which in that case would have disappeared.

At Goodhaab I repeatedly came across small bergs in the fiords, laden with mud and detritus, and sometimes carrying imbedded stones of moderate size. One of these I was induced to examine more closely than perhaps I should otherwise have done, having "stalked" what I conceived to be a large black bird perched halfway up on its face, and on close approach discovered it to be one of these impacted boulders, about a foot in diameter.

The large shoal called the "Tallert Bank," to which I have drawn attention in a former page as being composed of detritus brought down from the interior of the land by a river debouching under the great ice-blink, affords an example of the conditions under which the smaller class of bergs receive detritus. That

bank, which is a drift-bed now in process of formation, would in all probability present every condition, both as regards mineralogical composition and the character of its organic remains, that occurs in the ancient drift-beds of the Post-pliocene period.

Whilst at Julianshaab, I was informed by Mr. Hoyer, the Assistant Superintendent of the colony, who has explored the so-called continental ice of South Greenland for a considerable distance into the interior, that crevasses are occasionally to be met with, of no great width, but whose depth is so great that a fragment of ice dropped into them can be heard to reach the bottom after the lapse of a very considerable interval; whilst in some places the sound of running water and cascades at great depths can be distinctly recognized. The Esquimaux assert that, during the most severe period of the winter, the reindeer flock together in herds *under* the hollow portions of the continental ice, and that they actually find food, such as lichens, in these vast ice-vaulted wildernesses when none is attainable elsewhere. Without pretending to deal with the proofs that are required before such a statement can be accepted as a fact, I must say I am unable to adduce any weighty reasons why it should not be so; whilst, on the other hand, sundry plausible arguments could be brought forward which tend to show not only that such sub-glacial tracts *may*, but in all probability *do* exist.

In the event of a glacier forming in a valley traversed by a shallow stream during the warmer months, the first effect of the influx of a much augmented volume of water at a temperature considerably above freezing-point would be to produce a series of arched passages, which would subsequently increase in vertical dimensions in consequence of the obstructed outflow keeping them filled, and thus subject to a protracted thawing action. On the recurrence of winter, the onward progress of the glacier would more or less completely block up the outlet, without obliterating the previously formed subglacial channel. On the return of summer, the now enlarged channel would at once be filled up with water of sufficiently high temperature to extend its boundary walls still further, —these two operations being repeated indefinitely through a lapse of centuries, and eventually resulting in the subglacial tract referred to. Under the same circumstances the waters flowing down into this tract would convey and deposit the spores of lichens, and possibly the seeds of phanerogamic plants, which, on

the recession of the water at the close of the warm season, might germinate and gradually spread themselves.

Supposing the above theory to be admissible, it would throw some light on the cave deposits and remains. In the event of herds of animals, such as reindeer, congregating together in these subglacial valleys, should their egress be prevented by the collapse of portions of the glacier, or the sudden irruption of floods, they would be swept away with the current, and their remains imbedded in the drift-bed, such as escaped into the more elevated crevices and caves (which are nowhere more abundant than in the rock formation of South Greenland) dying there, and being after a time covered over with detritus.

Where the Ruminants had penetrated, the indigenous Carnivora would follow, and thus the remains of both orders might become mixed up in the same localities; whilst the drift-beds formed at the mouths of the valleys would become the receptacle for the remains of the entire local fauna of the period, terrestrial as well as marine.

Lastly, this view would tend to show that the deep furrows which occur on the upper surface of the ancient drift-beds and are generally found filled up with a muddy deposit, had been formed by the transit of ice-bergs, the traces of previously formed furrows having become obliterated by the gradual subsidence of gravel in lieu of the lighter mud originally occupying them.

Before closing my observations on icebergs, I would allude to an occurrence which, although at first sight paradoxical, admits of a very simple explanation. It must have fallen under notice again and again; but as it bears materially on the safety of submerged telegraphic cables, and has not been taken into consideration in connexion with that subject, I may be permitted to illustrate it. I allude to the case of bergs which require deeper water for their flotation, after being diminished in bulk by the breaking away of a portion, than they did previously, and the consequent possibility of their grounding and inflicting injury on a cable after having floated innocuously over the spur or shoal which is supposed to divert all bergs of sufficient volume to ground within the barrier. The subjoined woodcut represents an appearance I have repeatedly met with in bergs, both out at sea and in the fiords. The height of the example under notice was about 40 feet, its length being about 100 feet.

The shaded portion of fig. 1 shows the berg as seen above the water-level

A A,—one half of the original line of flotation *a a* being visible, the other half being submerged. The dotted outline gives an ideal view of the portion below water, the submerged half of the original line of flotation being shown, and the base of the berg *e f*. Fig. 2 gives an ideal view of the same as it appeared before the separation of the mass *d*, B B being the bed of the fiord.

Fig. 1.

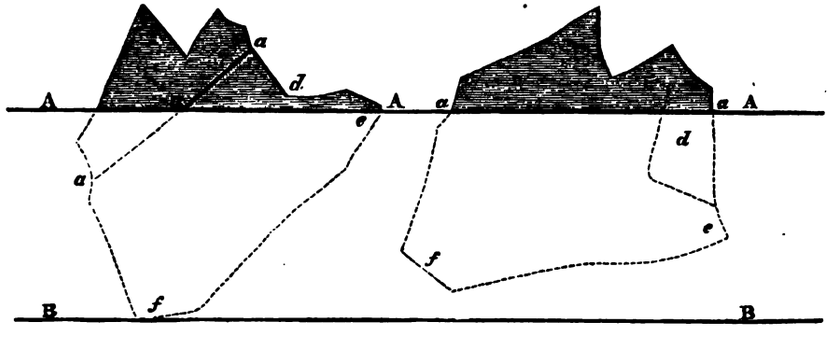


Fig. 2.

There are evidently but two modes in which the horizontal line, *a a*, could have been tilted up as seen in fig. 1; that is, either by the addition of a mass in the direction of *f*, or by the separation of a mass in the direction of *e*. Either of these causes might produce the result. In the case of floating pieces of ice, however, the latter would be the more likely occurrence; and in the example under notice, it was quite manifest, from the appearance of the surface, that a large mass had recently been detached at *d*. Such a mass, although materially adding to the cubical contents of the berg, would have the effect of distributing the weight equally round the centre of gravity, and of sustaining the portion at *f* at a higher level by acting as a counterpoise, as shown in fig. 2. On the other hand, it is evident that the separation of such a mass as *d* would at once throw the centre of gravity further towards *f*, and thus cause it to assume a deeper level, as in fig. 1.

Although these diagrams represent an imaginary case, in so far as the portion below water is concerned, there cannot be a doubt of the fact which they are intended to demonstrate, namely, that it is an error to assume that because a mass of ice drifts along in a given depth of water without touching the bottom, it may not, by such a process as has just been described, tilt over and immediately ground. It is obvious, therefore, that the mere circumstance of a fiord being

furnished with rocky spurs projecting into the sea at its entrance, or having a bar across its mouth upon which the depth of water is less than in the channel of the fiord itself, constitutes no protection to a telegraphic cable submerged along it, and that there is but one set of conditions which can be accepted as affording unquestionable security, namely, that furnished by a channel sufficiently deep to prevent the possibility of the largest bergs grounding under any circumstances whatever, and extending from deep water out at sea to the extreme verge of the terminus at which it is intended to land the cable. Instead of the grounding of bergs at a given distance from a coast-line affording this security, it proves the liability to the entrance of these masses wheresoever they can find a channel and atmospheric and tidal influences come into operation. Some channels are no doubt less liable than others to the entry of bergs, either on account of their direction with regard to prevailing winds and currents or their tortuousness; but the first obstacle must necessarily be regarded as uncertain in its results, whilst the rock or shore formation which invariably accompanies the second renders great fluctuations in the depths inevitable. In the case of channels through which the discharge of water from the land is so great as to oppose the entry of bergs, it is almost needless to say the action of boulders and abrading surfaces would only alter the kind of danger, without diminishing it.

On reference to the Map, it will be seen that, up to the period of our departure from Julianshaab, one line of soundings, divided into three sections with reference to the countries visited, has been completed, namely, from the Faröe Islands to Iceland, from Iceland to the east coast of Greenland, and from the south-western portion of Greenland to Hamilton's Inlet in Labrador, the last section having been re-traversed on the return voyage of the 'Bulldog.' Since our last approach to Greenland in the vicinity of Christian Sound, a fresh line has been entered on, stretching direct from Cape Farewell to Rockall. Since the 8th instant, four soundings have been taken, two of which present most interesting results, although in one of these only was material brought up from the bottom in sufficient quantity to indicate more than the fact of its having been reached by the sounding-machine.

In the first of these four soundings, which was taken in lat. 59° 48′ N., long. 37° W., the depth (1620 fathoms) is remarkable as showing a decrease of 336 fathoms in comparison with that of a sounding taken during the outward

voyage from Iceland to the east coast of Greenland, in nearly the same meridian, but in lat. 61° 57′ N. The second sounding, in lat. 59° 47′ N., long. 32° 43′ W., indicated a depth of 1168 fathoms, or a still greater decrease as compared with the depth of a sounding taken three degrees to the northward, the difference amounting to 404 fathoms. The third sounding, taken in lat. 59° 39′ N., long. 29° 38′ W., gave a depth of 748 fathoms only, or, as compared with a point four degrees to the northward and nearly in the same meridian of longitude, a decrease of 338 fathoms,—these three soundings jointly indicating that along a tract extending from the 29th to the 37th degree of west longitude, in the two lines separated by a mean interval of about three degrees of latitude, the more southerly line shows a mean decrease in depth of 360 fathoms.

The discovery of a plateau partially raised above the surrounding level of the sea-bed, when considered by itself, might naturally be regarded as an isolated fact of little import, and not necessarily dependent on any extraordinary convulsions of the earth's surface; but it assumes a very different aspect when viewed in connexion with historic records, which declare that dry land, or, at all events, land so partially submerged as to be a source of danger to navigators, actually existed several centuries ago in the locality referred to; and hence it would almost countenance the supposition that, at a still more remote period, this tract may have constituted one of the successive stepping-stones by which North-western Europe and the North American continent were united.

Although it is impossible to say how far the volcanic action, of which Iceland now constitutes the centre, may have extended in a southerly direction during past ages, when we take into consideration the distances to which such agencies have actually been known to extend, the occurrence within little more than half a century of volcanic action and land-subsidence considerably to the southward of Iceland, the line of this action as shown by the geological formation of Iceland itself, and the outlying centres of the recent convulsions alluded to, and, lastly, the drift of volcanic particles in a southerly and south-westerly direction, it seems far from improbable that the subsidence of the tract under notice may have resulted from similar agencies.

In some of the old charts, a dangerous reef or shoal, frequently referred to by the navigators of those days as the "sunken land of Buss," is laid down in lat. 57° 30′ N., long. 29° 50′ W. In a finely executed French chart, dated

Paris, 1777, by M. Fleurieu, this position is assigned to it; and in the same chart we find another shoal put down considerably to the eastward, namely, in lat. 59° 30′ N., long. 16° 50′ W., that is to say, about fifty or sixty miles from the north-western portion of the Rockall Shoal. Captain Sir J. Ross* alludes to both these shoals in the narrative of his voyage in 1818. He writes, "We came, "on the 8th of May, to a spot where a bank is laid down in Steel's chart as dis- "covered by Olof Kramer" (lat. 59° 28′, long. 17° 22′); "but we could find no "soundings in 130 fathoms, anywhere on or near the place." And again, "At "noon we found ourselves exactly in the latitude of the sunken land of Buss, as "it is laid down in some charts, namely, 57° 28′ N.; and being desirous of deter- "mining whether such a bank really existed in long. 29° 45′, we altered our "course for the purpose of ascertaining the fact." "At sunset, being near the "spot, shortened sail and hove to, in order to sound; but no bottom was found "in 180 fathoms. Our sounding was repeated every four miles, with no better "success."

In Captain Graah's narrative of a voyage to Greenland in 1828†, he says, "On the 25th we passed what is laid down in the charts under the name of the "Sunken-land-van-Buss—a danger made mention of even in the latest English "Sailing Directions, but which mariners may be now assured is altogether an "imaginary one. It is, by the way, remarkable enough, that precisely where the "Sunken-land-van-Buss is thus laid down, the ancient charts place Frisland, that "mysterious land which geographers have been so puzzled where to look for, "and which but very lately has been ascertained to be no other than the "Faröe Islands. This very erroneous location of Frisland serves, in my opinion, "to prove that Zeno (the Venetian navigator of the 14th century) was far from "having that intimate and accurate knowledge of our Northern Seas which "many give him credit for."

In the appendix to the same work, reference is made to "Ivar Bardsen's" Sailing Directions for navigating between Iceland and Greenland, which describe some rocks under the name of "Gunbiörn Skerries" as situated to the south-

* Voyage of Discovery made in H.M.S. 'Isabella and Alexander,' for the purpose of exploring Baffin's Bay, &c, by Sir John Ross, Capt. R.N. London, 1819, pp. 11 and 14.

† Narrative of an Expedition to the East Coast of Greenland, by Captain Graah, Royal Danish Navy. Translated from the Danish. London, 1837, p. 20.

westward, exactly midway between Iceland and Greenland, and recommend that a particular course should be steered in order to avoid the ice that had drifted down and "set itself fast" to these skerries. From what is above quoted, it will however be evident that Captain Graah discredited the existence of these skerries.

Mention is also made of land in this locality in Crantz's 'History of Greenland*.' In speaking of Sebastian Cabot as having been the first to penetrate into Davis Straits in 1497, Crantz adds, "A century before this, in 1380, we "read that Nicolas and Antonius Zeni, two noble Venetians, were carried off by "a storm from the coast of Iceland into the Deucaledonian Sea; and that in "lat. 58°, between Iceland and Greenland, they discovered a large island "inhabited by Christians, and covered with a hundred towns and villages, which "was called *West Friesland*. Since that time, however, we have not a syllable "of intelligence which can give an air of truth to this story. Frobisher in his "third voyage touched at a country in that latitude, and found the inhabitants "similar in all respects to the Greenlanders, whence he justly concluded that it "was a part of Greenland. Some persons, however, espouse the opinion that "this island has been swallowed up by an earthquake, and is the same with the "sunken land of Buss, marked on the charts, and which is dreaded by seamen "from the shallowness of the incumbent water and the furious dashing of the "waves."

Without further multiplying the statements of the older writers on this subject, I think, notwithstanding the utter distrust with which they have been regarded, that there is quite sufficient evidence in the distinct declarations of the Venetian and Norwegian navigators, coupled with those of later voyagers who speak of a shoal or *sunk land*, and the remarkable confirmation afforded by the recent soundings, to establish the probability that a tract of land or island did once exist between the 27th and 29th degrees of N. latitude and the 59th and 60th degrees of W. longitude, and that it was either submerged suddenly by some tremendous volcanic action, or subsided slowly, leaving behind only the shoal which is now completely hidden below the surface.

According to present information, the isolated fact is established, that about midway between the 27th and 32nd degrees of W. longitude, where on the one side the depth is 1160 fathoms, and on the other 1260 fathoms, the water shoals

* 'History of Greenland,' from the German, by David Crantz. London: 1820, p. 250.

to 748 fathoms. Judging from the contour of the Atlantic basin, and the known course of the Gulf Stream, which at the present day sweeps directly along this 200-mile longitudinal tract, an increase and not a decrease of depth might naturally have been expected. It is necessary for me to state that the selection of the spot at which the 748-fathom sounding was taken bore no reference whatever to the question now at issue, but rather to the extreme difficulties attending the operation of sounding at all during the tempestuous weather the ship encountered, and that such decrease in depth was wholly unlooked for: and hence, although the allusion to such a depth as being shoal water may appear somewhat inappropriate, it must be borne in mind that nothing could be more unlikely than that a spot so selected should represent the shallowest water, or that we should find least depth at two degrees northward of the point indicated in the old charts, and which, if it ever existed as dry land, must have been the most elevated and therefore the last submerged portion of the tract in question.

When we take into consideration that Sir John Ross sounded only to a depth of 180 fathoms without striking bottom, and that until a very recent date the idea of systematically surveying depths estimated by thousands instead of hundreds of fathoms was never entertained, it becomes easy to account for the failure of those navigators who deny the existence of any submerged land, to trace either its position or its boundaries.

It is much more probable that spots occur along this submerged tract on which the depth of water is reduced far below that indicated by the sounding, than that the shallowest point should have been accidentally struck; and even supposing that no very considerable diminution should be met with, and that it becomes necessary to assume a subsidence of several hundred feet at the spot last submerged, the case would by no means be without parallel. On the contrary, taking as our examples Sweden in the one direction, and Greenland in the other, ample geological evidence can be adduced to prove that gradual elevation in the one case, and gradual subsidence in the other, have been and continue in operation. In Sweden, we find that land now elevated several hundred feet above the present sea-level must once have constituted the bed of the ocean. Were it possible to observe the traces of ancient water-levels on the now submerged slopes of the Greenland fiords, the evidence would, no doubt, show that depressions, equalling in degree any that may be considered necessary

in order to account for the "sunken land" under notice, have taken place, not under the operation of sudden volcanic convulsions, but as the result of a gradual process acting uninterruptedly through vast periods of time. It is somewhat singular that Captain Graah, who was the foremost to repudiate the idea of an island or shoal having existed in the locality assigned to it, should, in 1823, have been the first to notice the extensive subsidence that had taken place along the western shores of Greenland*.

Lastly, it must not be forgotten that, within the memory of man, one if not two islands have been raised up out of the sea, and again submerged, off the south-west coast of Iceland, in a line which, if extended, would very nearly intersect the position assigned to the "sunken land of Buss;" and although, as before stated, active volcanic disturbance is not requisite to produce the effect in question, there is more likelihood of its taking place in regions subject to such disturbances than in regions never under this influence.

I shall have occasion, in a future chapter, to draw attention to the evidences afforded by certain creatures, whose normal habitats are in comparatively shallow zones, having become acclimatized, perhaps through a long series of generations, and rendered capable of maintaining existence at depths vastly in excess of those which may be regarded as normal in other latitudes. One example is drawn from the west coast of Greenland, in lat. 64° 14′ N.; the other from a point about midway between the most southern part of Greenland and Rockall, in lat. 59° 27′, long. 26° 40′ W. In now drawing attention to these two cases, I am desirous of showing that, irrespective of the facts already noticed, there are circumstances which render it probable that subsidence has taken place, and is still taking place, along the tract in question, and, further, that the line of subsidence between South Greenland and Rockall, thus indicated, tallies in a very remarkable manner with the ancient boundary line suggested by Sir John Richardson, and acquiesced in by the late Professor Edward Forbes, on independent grounds, as marking the northern limit of the Atlantic at the period at which it was separated from the great Arctic basin. In the concluding portion of 'The Natural History of the European Seas,' Mr. R. Godwin-Austen thus describes the boundary in question:—"A line from Newfoundland to Cape "Farewell, thence across the Atlantic of Iceland and the Faröe Archipelago,

* See Sir Charles Lyell's 'Principles Geology.' London, 1853, p. 530.

"represents, conjecturally, the northern limitation of the Atlantic at the time "when it did not communicate with the Arctic basin*,"—thus lending a powerful confirmation to the view I have endeavoured to establish.

At the present time, when the attention of naturalists is directed to the evidences of the community of types ascribable to the animals and plants of Europe and the North American Continent, and the question to be decided is whether the ancient communication between these two countries was effected across the North Atlantic or North Pacific Oceans, it is of the utmost consequence that every fact likely to throw light upon it should be made public. Under this impression I have been induced to exhume the evidences above cited, and to append my reasons for inclining to a belief that the tract over which the 'Bulldog' sounded may have formed, in ages gone by, one of the stepping-stones which connected the eastern and western hemispheres of the globe.

It has been stated that two of the soundings taken since the 'Bulldog' entered on the survey of the direct route between Cape Farewell and Rockall have proved of high interest. The first of these, which indicated 748 fathoms in a part of the North Atlantic basin at which we might reasonably have expected to find an increase instead of a diminution in depth, has already been noticed. The second can only be cursorily touched upon in this place, inasmuch as it involves the entire question of life at extreme depths in the sea, and must therefore be discussed at length hereafter. This sounding far exceeds in importance any previous sounding on record; for not only does it for ever determine the fact that animal existence may be maintained at depths vastly greater than by most persons has been believed possible, but it proves the fallacy of several of the conditions which have heretofore been supposed to limit the bathymetrical distribution of animal life, and points to the existence of a new series of creatures peopling the deeper abysses of the ocean, and destined, perhaps, to furnish many of the missing links between the submarine faunas of the Past and Present. That single sounding, I may be permitted to say, compensates for every disappointment that weather and accident may previously have engendered. At the eleventh hour, and under circumstances the most unfavourable for searching out its secrets, the deep has sent forth the long-coveted

* 'The Natural History of the European Seas,' by the late Professor Edward Forbes, F.R.S. Edited and continued by R. Godwin-Austen, F.R.S. London, 1859, p. 286.

message. What mechanical ingenuity failed to achieve, hunger or curiosity accomplished; and thus whilst the sounding-apparatus only succeeded in bringing up from a depth of 1260 fathoms a number of minute shell-covered creatures, so simply organized as to render them incapable of perceiving or escaping a danger, thirteen star-fishes, ranging in diameter from 2 to 5 inches, came up convulsively embracing a portion of the sounding-line which had been paid out in excess of the already ascertained depth and rested for a sufficient period at the bottom to permit of their attaching themselves to it. These star-fishes arrived at the surface in a living condition, and, what is still more extraordinary, continued to move their long spine-covered rays for a quarter of an hour afterwards—clearly proving that, if their adherence to the sounding-line was due, in the earlier stage of their progress upwards, to a clonic spasm of the muscular tissue, neither life nor nervous energy ceased till after the lapse of the period mentioned.

This sounding, taken at a distance of about three degrees to the eastward of the position at which a depth of 748 fathoms was met with, indicates an increase of 572 fathoms, or about 150 fathoms in excess of the depth ascertained at the same distance in the westward direction. The discovery of the star-fishes in this situation, although it can in nowise detract from the validity of the fact regarding the presence of living creatures at the greatest depths, may nevertheless be associated in some measure with the subsidence of the sea-bed, inasmuch as, during the lapse of ages, the successive descendants of the star-fishes that originally inhabited the shallower waters present before such subsidence took place may, by degrees, have become capable of maintaining their existence under the now altered conditions. Whether this has or has not been the case must unfortunately remain for ever a matter of mere speculation; but, supposing it to have been so, it would only tend to prove that, in certain instances, transitional habits may be acquired without producing transitional characters; and if the possibility of animal life at extreme depths be admitted (as I take for granted it must be henceforth), it is just as reasonable to assume that the ancestors of animals now capable of existing in shoal water may have lived originally at extreme depths, the one transition being in nowise more wonderful than the other. The hard-shelled Echinoderms are constituted for creeping, and not for swimming; and hence, if it could be shown that any of them (such as *Palmipes*,

for example) are capable of floating or swimming, the case would at once be altered, and there would be fair ground for assuming that, whilst their ancestors originally belonged to the free-rayed group and inhabited great depths, the descendants of these had by degrees developed the membrane-like expansion between the rays in order to enable them to remove to shallow water on the subsidence of the sea-bed. It is well known, however, that neither *Palmipes* nor any of the other hard-shelled Echinoderms are floating animals; and accordingly the proof that those brought up by the sounding-line actually travelled from the bottom, and not from some superincumbent stratum of water, must be regarded as conclusive. It is only necessary to add that the nearest point of Iceland to the spot at which the sounding was taken is 250 miles distant, whilst between it and the nearest point of Greenland the distance is 500 miles.

Throughout the day large flocks of Dovekies have flown across in a south-westerly direction, as if migrating from Iceland to Newfoundland or the southern portion of Labrador. Measuring from the nearest point to point of land, these birds would have to traverse a distance of 1200 miles, which, at a speed of thirty miles an hour, would involve forty hours' incessant flight. Although migrations across even greater areas of open sea are known to be effected by many species of purely aquatic birds, it becomes difficult to conceive how small wading birds, such as the Sandpipers, can accomplish a similar journey. A number of the latter, in pairs, flew past, taking the same course; but, from the manner in which they invariably hovered round the ship for a short time, as if anxious to alight even at this early stage of their voyage, it would almost seem probable that their instincts had been at fault when they selected their route. Should this be the case, and the circumstance I have mentioned be one of frequent occurrence, very large numbers of these birds must perish annually in the middle of the sea, their soft parts being gradually devoured by the countless great and small zoophagists that inhabit its waters, whilst their skeletons subside and become ultimately entombed amongst the deposits at the bottom.

Oct. 19.—Rekiavik. After having encountered a continuous succession of the heaviest gales since leaving Greenland, the 'Bulldog' once more anchored here this afternoon, in order to coal and repair damages.

In approaching Cape Rekianess last night, about 11 P.M., we passed close by an isolated basaltic rock, known as the "Blinde Skier," or "Grenadier's Cap,"

which rises up perpendicularly from the sea to the height of 80 feet. It is a curious fact, that both this rock and one of a similar kind on the Rockall shoal present so close a resemblance to a ship under sail, that it is almost impossible to believe they are anything else, when seen from certain points of the compass. By a sounding taken at a distance of about a quarter of a mile from the "Blinde Skier," the bottom was shown to consist of coarse basaltic sand and shell-débris. The period at which this rock was heaved up is unknown; but there can be no doubt of its having maintained its present position unmoved for centuries, during which both the mainland of Iceland and the intervening portion of the sea-bed have undergone several very severe convulsions. Thus in 1783, the year in which the most tremendous disturbances on record took place in Iceland, a submarine volcano burst into action in lat. 63° 25′ N., long. 23° 44′ W., at a distance of ten or twelve miles from the Blinde Skier rock, and thirty miles to the south-westward of Cape Rekianess, during which an island of considerable size and height was thrown up. This island was named "Nynoë," or the New Island, and claimed by the King of Denmark; but, before a year had elapsed, it again subsided, leaving nothing but a sunken reef to indicate its position. In 1830 a smaller island was ejected, somewhat nearer to the coast; but it was in like manner submerged after a brief interval.

Oct. 28.—Today the 'Bulldog' again proceeded to the southward with a view to continue the line of soundings between the point at which she diverged *en route* to Iceland and Rockall.

From a few soundings taken between Rekianess and the Blinde Skier, it appears that the obsidian-like detritus, of which mention has been made in Chapter II., commences somewhat to the eastward of the latter, and stretches to the north-westward in a belt of about twenty miles in diameter, fringing the western shore of the promontory; whilst to the westward of this, and running parallel with it, a belt of rolled basaltic drift ascends and crosses the first line of soundings, as formerly indicated. Although no data were afforded, during the outward voyage between Iceland and Greenland, for determining the source from which the rolled fragments of basalt were derived, these latter soundings prove that the belt in question is borne northwards by the eastern margin of that portion of the Gulf Stream which splits on coming across the Blinde Skier shoal, ascends in a northerly direction towards Faxe Fiord, and then sweeps up the

west side of Iceland. This ascending current, it may be observed, would operate continuously along the whole of this shoal-water tract, irrespectively of the ordinary tidal current, which can only affect the superficial stratum of water. Under any other circumstances, inasmuch as it has already been shown that this tract has been under the immediate influence of recent volcanic convulsions, the belt of basaltic gravel, or, at any rate, that portion of it in the vicinity of the Blinde Skier which has altogether escaped such volcanic action, must have been buried under a similar obsidian-like deposit. Should a telegraphic cable ever be carried along the North-Atlantic route, there is good ground for believing that the surest method of avoiding the danger of submarine volcanic action, to which the greater portion of the southern district of Iceland is liable, would be to bring the wire across from Ireland, *viâ* Rockall, to the Blinde Skier, and thence direct to Labrador. If injury from volcanic disturbance were to take place at all in the case of a wire following this route, it would in all probability occur between the Blinde Skier and the mainland, to which there might be a short branch-line, and not between the Blinde Skier and Labrador, as no recent volcanic action has been known to take place in that direction.

Nov. 11.—The few remaining soundings having been concluded in defiance of a still further continuance of stormy weather, and the supply of coal being again exhausted, the 'Bulldog' today put into Killibegs, County Donegal. At that port I left the ship and bade adieu to my messmates, whose friendly companionship I shall always recollect with feelings of sincere pleasure.

PART II.

THE BATHYMETRICAL LIMITS OF ANIMAL LIFE IN THE OCEAN.

ON no question connected with marine zoology does the information of naturalists appear to have been so singularly defective as on the bathymetrical limit of animal life in the ocean. When it is borne in mind that, until a very recent period, but a few isolated attempts had been made to bring up "specimens of bottom" from deep water, and that the "antibiotic view" rested exclusively on the foregone conclusion that no organized creature "of a kind analogous to those with which we are acquainted" could exist under the extraordinary conditions of pressure, aëration, temperature, and light which prevail on the deep-sea bed, it can hardly be wondered at that the clearest proofs should have been necessary in order to establish an opposite opinion. But it is nevertheless surprising that the antibiotic view, based as it was altogether on negative evidence, should have remained unimpugned for nearly half a century after the publication of statements which, although meagre to a degree when considered with reference to the importance of the subject, were calculated to throw reasonable doubt upon it and consequently deserved most serious consideration.

In 1819, the late Sir John Ross published an account of his having obtained in Baffin's Bay various "sea-worms," "shrimps," and other creatures, from depths greatly exceeding those at which animal life was supposed to become extinct; and nearly thirty years subsequently, Sir James Ross also reported having dredged up living creatures from great depths in the Antarctic seas. Hence, whatever weight may have attached to the testimony of these distinguished Arctic navigators on other subjects, it is evident that some deep-rooted

doubt forbade the recognition of statements so opposed to the established views of naturalists, and that nothing but the foregone conclusion already referred to could have led to their being so unhesitatingly ignored. That the presence of animal life at great depths was ignored until the period at which the question was unequivocally set at rest by the capture of the star-fishes on board the 'Bulldog' may be fairly inferred, I think, from the circumstance that, with one exception entirely unconnected with the above observations, no naturalist or physiologist had previously ventured to prove that animal life extends indefinitely below the limit of the deep-coral zone; but, on the contrary, so universal was the assent given, both in Europe and America, to the views propounded by the late Professor Edward Forbes, that, in one of the most recent and authoritative works published on the subject, the belief is unhesitatingly expressed, that, at 300 fathoms below the surface of the sea, life is extinct.

A few extracts from the writings of some of the most eminent authorities on the geographical distribution of marine creatures will suffice to show that, up to the period at which my Notes on the presence of animal life at vast depths in the Ocean * were published (that is, immediately after the termination of the North-Atlantic Cruise in 1860), "the extreme depressions of the sea, like the extreme elevations of the land, were supposed to be barren and lifeless solitudes;" and they will at the same time prove, whatever may have been the value of the data furnished by any previous soundings, that an entirely new series of proofs was rendered indispensable, before the fact of the extension of the bathymetrical limits of life by many hundred additional fathoms could be presented to the scientific public as deserving their credence.

In 'The Natural History of the European Seas †,' Professor Edward Forbes writes as follows:—"Last and lowest of our regions of submarine existence is that of the *deep-sea corals*, so named on account of the great stony zoophytes characteristic of it in the oceanic seas of Europe. In its depths the number of peculiar creatures is few, yet sufficient to give a marked character to it; whilst the other portions of its population are derived from the higher zones, and must

* 'Notes on the Presence of Animal Life at Vast Depths in the Sea.' Taylor & Francis: Lond., 1860.

† 'The Natural History of the European Seas,' by the late Professor Edward Forbes, F.R.S. Edited by R. G.-Austen, F.R.S. London, 1859: pp. 11, 26, and 246.

be regarded as colonists. As we descend deeper and deeper in this region, its inhabitants become more and more modified, and fewer and fewer, indicating our approach toward an abyss where life is either extinguished or exhibits but a few sparks to mark its lingering existence. Its confines are yet undetermined, and it is in the exploration of this vast deep-sea region that the finest field for submarine discovery yet remains." Again, alluding to the entirely new field of inquiry opened out to the naturalist by the investigation of the various provinces of marine life, and the delight experienced by him the first time he "saw the dredge hauled up after it had been dragging the sea-bottom at a depth of more than 100 fathoms," he says, "Fishing-lines had now and then entangled creatures at as great and greater depths, but these were few and far between, and only served to whet our curiosity, without affording the information we thirsted for."

Towards the close of the same volume, Mr. R. Godwin-Austen expresses his adherence to the same opinions, in these words:—"The sublittoral zone of every sea and ocean presents the fulness of its fauna; and from that it decreases progressively and rapidly, till, in regions far within those in which the finer sedimentary deposits are distributed, animal life altogether ceases. Far beyond the zones where the members of a marine fauna *live*, there are areas of wide extent where animals of oceanic habits strew their delicate structures: this is the zone of the 'free-swimmers'—Pteropods, Nucleobranchs, Pelagic Cephalopods, and Crustaceans. The depositions of all past times present every gradation of bathymetrical distribution, down to the 'azoic zones' of depth; and the mere geologist must beware not to misinterpret the evidence presented to him, and suppose that some old world of waters was without life, merely because he finds no traces of it. Still less, on such negative evidence, must he speculate as to the 'dawn of life' and 'primordial zones.' The history of our own seas, and of all seas, teaches us that there is a law of proportion in the classes and orders of the living things that dwell there, and that the presence of one form is safe ground of inference as to the co-existence of countless others."

Sir Charles Lyell, in his remarks on the migrations of the Testacea*, says, "Professor E. Forbes has shown, as the result of his dredging in the Ægean Sea, that there are eight well-marked regions of depth, each characterized by its own testaceous fauna." And again, "a copious list of species is given as characteristic

* Lyell's 'Principles of Geology.' London, 1853: pp. 649 and 773.

of each region down to the seventh, which lies between the depths of 80 and 105 fathoms, all the inhabited space below this being included in the eighth province, where no less than 65 species of Testacea have been taken." In describing the "imbedding of the remains of marine plants and animals," he writes as follows:—"I have already stated that at a depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smith found a gravelly bottom, with fragments of broken shells, carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting-power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for, even in our own colder latitudes, the depths at which living marine animals abound is considerable. Captain Vidal ascertained, by soundings off Tory Island, on the north-west coast of Ireland, that Crustacea, Star-fish, and Testacea occurred at various depths between 50 and 100 fathoms; and he drew up Dentalia from the mud of Galway Bay, in 230 and 240 *fathoms* water."

Mr. Page, in 'The Advanced Text-Book of Geology*,' says that, "according to experiment, water at the depth of 1000 feet is compressed $\frac{1}{340}$th of its own bulk; and at this rate of compression we know that at great depths animal and vegetable life, as known to us, cannot possibly exist,—the extreme depressions of seas being thus, like the extreme elevations of the land, barren and lifeless solitudes. Further, at great depths, sand, mud, and all loose débris will be compressed and consolidated; and, according to the experiments of Sir James Hall, even limestone could be fused without the loss of its carbonic acid. The effect of depth in regulating the distribution of species is one of the prettiest problems in zoology, every zone from the shore seawards being characterized by different specific forms; and, as will hereafter be seen, the comparative depths of seas of deposit may be ascertained with considerable certainty by a study of the fossils found in such deposits."

According to Messrs. Agassiz and Gould†, "The depths of the ocean are quite

* 'Advanced Text-Book of Geology, Descriptive and Industrial,' by David Page, F.G.S. London, 1856: p. 20.

† 'Outlines of Comparative Physiology,' by Professors Agassiz and Gould. London, 1851: p. 365.

as impassable for marine species as high mountains are for terrestrial animals. It would be quite as difficult for a fish or a mollusk to cross from the coast of Europe to the coast of America, as it would be for a reindeer to pass from the Arctic to the Antarctic regions across the torrid zone. Experiments of dredging in very deep water have also taught us that the abyss of the ocean is nearly a desert. Not only are no materials found there for sustenance, but it is doubtful if animals could sustain the pressure of so great a column of water, although many of them are provided with a system of pores which enable them to sustain a much greater pressure than terrestrial animals."

The same distinguished authorities have, at a still more recent date, expressed similar opinions. Mr. Marcou, a member of the Boston Society of Natural History (U.S.), having informed that Society that he had read in an English journal an account of the capture of the star-fishes (as given by me in my published notes, and also in a lecture at the Royal Institution of Great Britain, in February 1861), Messrs. Agassiz and Gould intimated their doubts of the creatures having been brought up from the depth stated, and suggested that they might have become attached to the line at a point far nearer to the surface.

The following passages, quoted from the invaluable work written by Sir Henry De la Beche thirty years ago*, when the researches of Sir John Ross were comparatively speaking of recent date, clearly show the opinions then entertained on the subject:—"We have hitherto considered marine animal life with reference to creatures living in particular depths of water, and which, when we regard those of the ocean, are comparatively shallow. The surface of the deep ocean teems with animal life, and is probably not less well proportionably tenanted down to depths where, from the want of the necessary conditions, it ceases to exist. . . . What the actual depth may be beneath which animal life does not exist in the ocean, we have yet no good data for ascertaining; but that there must be such a limit, to at least any kind of life analogous to that with which we are acquainted, there can be little doubt."

Professor Löven, in discussing the bathymetrical limits of submarine life in the Scandinavian seas†, alludes to three forms of Echinoderms living in the

* 'Researches in Theoretical Geology,' by H. T. De la Beche, F.R.S., &c. &c. London, 1834: pp. 262, 263.

† British Association Reports, 1844, vol. xiii. p. 50.

deep-coral zone as low down as the fisherman's line can be sunk, and adds, "As to the point at which animal life ceases, it must be somewhere; but with us it is unknown. As the vegetation ceases at a line far above the deepest regions of animal life, of course the zoophagous mollusca are altogether predominant in these parts, whilst the phytophagous are more peculiar to the upper regions."

And lastly, Professor Phillips, in a very recent work on the 'Origin and Succession of Life on the Earth*,' sums up what was known regarding the "influence of depth on the distribution of life in the sea" with this observation—"That it appears that the relative fertility of the several zones decreases towards zero; and it is believed that at 300 fathoms life is extinct."

Having thus shown how universally the opinion has been entertained that animal life is limited to depths which vary slightly in different localities with the downward range of the deep-coral zone, I would now direct attention to the nature of the evidence that has hitherto been adduced in support of an opposite view, by three writers whose names will always be associated with great scientific discoveries in their respective departments, namely, Sir John Ross, Sir James Ross, and Professor Ehrenberg.

In order to remove all doubt as to the value of the data furnished by Sir John Ross's soundings in 1818†, I subjoin such extracts from his work as bear at all on the subject, premising that, out of 59 soundings at depths exceeding 100 fathoms, 23 ranged from 270 to 1050 fathoms,—the apparatus employed being the "deep-sea clams" specially designed by Sir John Ross for deep-sea dredging.

On the 31st of August, lat. 74° 03′ N., long. 81° 28′ W., he writes as follows:—"About six it fell nearly calm for a short time, and we sounded with the deep-sea clams, which brought up a quantity of mud, in which were five worms of a species that had not been seen before. There were only 650 fathoms of line out, consequently there could not be more than that depth of water; but there might have been much less, which was probably the case, as the swell was so great that it was uncertain, after 200 fathoms, when the machine reached the bottom."

* 'Life on the Earth, its Origin and Succession,' by John Phillips, M.A., LL.D., F.R.S., &c. &c. London, 1860: p. 16 *et seq.*

† 'A Voyage of Discovery for the purpose of Exploring Baffin's Bay,' by Sir John Ross, K.S., Royal Navy. London, 1819: vol. i. pp. 247, 251, and vol. ii. pp. 5, 49.

On the 1st of September, lat. 73° 37′ N., long. 75° 25′ W., it is stated that "soundings were obtained correctly in 1000 fathoms, consisting of soft mud in which there were worms; and entangled on the sounding-line, at the depth of 800 fathoms, was found a beautiful Caput Medusæ: these were carefully preserved, and will be found described in the appendix*."

On the 6th of September, lat. 72° 23′ N., long. 73° 07′ W., "At six, it being quite calm, and the water smooth, we sounded with the deep-sea clams, and found 1050 fathoms, which were the deepest soundings ever reached in Baffin's Bay. As we had only 120 fathoms fifteen miles further north, it is evident that the bottom of the sea, like the land, must here be very mountainous. The mud at the bottom was so soft that the instrument was completely buried, and it required considerable force to draw it out. The sea being a dead calm, the line was perfectly perpendicular, and we had a good opportunity of obtaining the exact depth before it started out of the ground. The instrument came up completely full, containing about six pounds of mud, mixed with a few stones and some sand. This mud was much coarser than that which we had before obtained, and was also of a much looser nature. When the line came up,

* The whole information furnished in the appendix with reference to the organisms procured in these soundings is given below—

"Class CRUSTACEA.

Genus HIPPOLYTE, Leach.

Species.—Having mislaid the specimen, I cannot give a description of it.

Genus GAMMARUS, Latreille.

Species *Sabini*.—Segmentis dorsalibus postice falcato-productis. Baffin's Bay. Captain Sabine.

Class ANNELIDES, Cuvier.

Genus NEREIS, Linné.

Species *Phyllophora*.—Ore edentulo, pedibus basi lamellis foliosis instructis. Baffin's Bay.

Genus LEPIDONOTUS, Leach.

Species *Rossii*.—Pedibus densissime testaceo hirsutis, squamis dorsalibus cærulescente-griseis. Baffin's Bay, amongst soundings.

Type RADIATA.

Class ECHINODERMATA.

Genus GORGONOCEPHALUS, Leach (1815). EURYALE, Lamarck (1816).

Species *Arcticus*.—Corpore supra glabro, radiatim costato, costis tuberculatis; radiis longissimis, tenuibus, supra granulatis, articulis (apicalibus præsertim) distinctissimis. Expansion 2 feet. Baffin's Bay. Captain J. Ross."

a small star-fish was found attached to it, below the point marking 800 fathoms."

And lastly, on the 2nd of October, lat. 62° N., long. 62° 25′ W., "Before noon it fell calm and became foggy. We sounded in 650 fathoms, and obtained from the bottom several small stones and shells." In the table of soundings in the appendix it is mentioned that "Serpulæ, shrimps, and fragments of shells" were contained in this material.

If we bear in mind that the maintenance of animal life has been held to be impossible at great depths, on account of certain physical conditions which have been clearly and repeatedly laid down, we can readily understand why these bare statements should have been disregarded; for, on carefully weighing the evidence they supply, it will be found, whilst no facts whatever are advanced to show the fallacy of the received opinions concerning the bathymetrical limits of marine life, that the whole of the details bearing on the vitality or otherwise of the creatures brought up are withheld; and, moreover, it is irreconcilable with what we know of the habits and structure of the Echinoderms to suppose that the "Caput Medusæ" (Euryale) and "small star-fish" referred to could have been found free-floating and alive at a distance of 200 fathoms from the bottom.

In Sir James Ross's Voyage to the Antarctic regions between the years 1839 and 1843*, the following passage occurs:—"January 19, 1841. Becalmed for two or three hours after noon; the dredge was put over in 270 fathoms water, and after trailing on the ground for some time was hauled in." After detailing the characters of certain pieces of rock brought up, and which are stated to have been deposited probably by an iceberg, he continues, "Besides this there were a great many stones of various kinds of granitic and volcanic structure; but the most remarkable circumstance was drawing up from so great a depth beautiful specimens of living coral, which naturalists and geologists have hitherto concurred in believing unable to work beyond the pressure of a few fathoms below the surface. Corallines, Flustræ, and a great variety of marine invertebrate animals, also came up in the net, showing an abundance and great variety of animal life. Amongst them I detected two species of Pycdogonum; Idotæa

* 'A Voyage of Discovery in the Southern and Antarctic Regions,' by Captain Sir James Clark Ross, R.N., K.N.T., F.R.S., &c. &c. London, 1847: vol. i. p. 201 *et seq.*

Baffini, hitherto considered peculiar to the Arctic seas; a Chiton, seven or eight bivalves and univalves, an unknown species of *Gammarus*, and two kinds of Serpula adhering to the pebbles and shells." After stating that an account of these, by Charles Stokes, Esq., appears in the appendix, he adds, "It was interesting amongst these creatures to recognize several that I had been in the habit of taking in equally high northern latitudes; and, although contrary to the general belief of naturalists, I have no doubt that from however great a depth we may be enabled to bring up the mud and stones of the bed of the ocean, we shall find them teeming with animal life; the extreme pressure at the greatest depth does not appear to affect these creatures; hitherto we have not been able to determine this point beyond a thousand fathoms, but from that depth several shell-fish have been brought up with the mud"*.

It will thus be seen that Sir James Ross alluded to Sir John Ross's sounding taken in 1819, when he referred to "shell-fish" having been obtained with the mud from a depth of a thousand fathoms,—there being no prior sounding described by him as taken in the Antarctic regions, in which living creatures were brought up at as great a depth as 270 fathoms, although subsequently Crustacea were brought up from 400 fathoms. I should not have deemed it necessary to point out the misconception which has arisen on this subject, had it not become general. Thus Mrs. Somerville declares†, in language distinctly denoting its reference to this sounding, that "before Sir James Ross's voyage to the Antarctic regions, the profound and dark abysses of the ocean were supposed to be entirely destitute of animal life; now it may be presumed that no part is uninhabited, since during that expedition live creatures were fished up from a depth of 6000 feet." In attempting to reconcile these

* Under the head of "Remarks on some corals obtained from great depths in the Antarctic Ocean," in a letter from Charles Stokes, Esq., F.R.S., in the appendix to Sir John Ross's work, Mr. Stokes, after alluding to a previous sounding at 400 fathoms, in which none of the shells and corals "appear to have been brought up in a living state," enters into a description of the organisms obtained in the sounding to which the above extract refers, and states that a small piece of "Retepora cellulosa," and a "Retepora or Hornera" resembling "H. frondiculata" of Lamouroux, were evidently taken in a living condition, adding his surprise at these and certain other organisms having been found, "except in a warm climate and at a small depth," and antithetically pointing out the occurrence of living specimens of a species of "Premnoa" at from 150 to 300 fathoms on the coast of Norway. (Appendix to Sir James Ross's work, vol. i. p. 334 *et seq.*)

† 'Physical Geography,' by Mary Somerville. London, 1851: vol. ii. p. 246.

facts, I desire to do justice both to Sir James Ross, who unquestionably perceived the full force of Sir John Ross's researches, and to Mrs. Somerville, who, in defiance of the unbelief of "naturalists and geologists," recognized the all-pervading principle of life where its presence had been so long and so obstinately repudiated.

In the portion of this work specially devoted to the history of the Rhizopods, I shall have occasion to state in detail my reasons for differing, on many very important points, from an authority to whom all who have studied the minute forms of the animal and vegetable kingdoms must look up with deference. At present I would merely observe that, whilst I am fully convinced of the vitality of the organisms to which Professor Ehrenberg refers, even at the extreme depths at which they are occasionally found, I cannot for a moment subscribe to the opinion that such vitality is demonstrated, as he most distinctly asserts it to be, by the presence of the soft parts contained within their shells. There are several strong collateral reasons for assuming that they normally live at the bottom; but when all these are added together, it still remains impossible to say that the fact is fully substantiated. It is far from improbable that the only absolute proof by which the question can be determined may yet be obtained—namely, that which would be afforded by distinct vital movements in the organisms after reaching the surface. For, if it is possible for creatures of a much higher type of structure to retain their vitality (as I shall presently show to be the case) after being brought up from equally vast depths, we are fully justified in assuming that creatures of such a simple type as the Foraminifera and Polycystina may retain their vitality under similar circumstances. If we turn to the evidence afforded by the fossil forms of these lower organisms, we find abundant reason for believing them to be fitted to undergo, with impunity, changes in the conditions by which they are surrounded far greater than could be borne by organisms of a higher order. Thus, it is well known that they command not only a much wider geographical range, both as regards recent and fossil forms, but that species living at the present day extend back to periods infinitely more distant in the world's history. But, whatever degree of probability may attach to the opinion that the Foraminifera and Polycystina of the soundings live and multiply at the depths from which the sounding-machine occasionally brings them, we must never lose sight of the fact that between probability and proof

there is a wide difference, and that, whilst the one may be said to be established on much stronger grounds than that adduced by Professor Ehrenberg, the other still remains to reward some patient labourer in the domain of microscopical natural history.

The presence of the sarcode, apart from other evidence, proves nothing beyond the powerful preservative effects of sea-water, surcharged, under a stupendous pressure, with its saline constituents. I have at the present time Foraminifera obtained, in a living condition at a depth of 100 fathoms, five years ago. These are, as a matter of course, dead; yet they retain their sarcode unchanged in quantity, in bulk, and in colour, and differing only from recent living sarcode in a somewhat diminished degree of viscidity. The pure Globigerina-deposits of the North Atlantic, obtained a year and a half ago, in like manner retain their sarcodic contents equally unchanged. It is highly probable, for reasons hereafter to be adduced, that these also were alive when taken at the bottom; but it is equally certain that they are dead now, and that they have been so, at all events, since a very brief period after they quitted their native element. It is necessary to mention these circumstances, inasmuch as Professor Ehrenberg has not only based the vitality of the Foraminifera, Polycystina, and Diatomaceæ on this single character, but has maintained that vitality has been retained by some of these organisms for several years, during which they had been preserved in closed bottles.

In a paper communicated to 'The Annals and Magazine of Natural History,' in 1844*, "On Various Materials obtained from the Residue of Melted Pancake-ice in the South Polar Regions," the statements on these points are so remarkable and explicit that it is necessary to quote them. After giving a list of "Siliceous Polygastrica" (Diatomaceæ and Polycystina), "Siliceous Phytolitharia" (principally Sponge-spicules), and "Calcareous Polythalamia" (Foraminifera), it is stated that, "In several forms of the genus *Coscinodiscus* their green *ovaries* were recognizable; consequently they must have been alive." And again, with reference to the residue of another specimen of similar material from those regions, containing "Siliceous Polygastrica and Siliceous Phytolitharia," Professor Ehrenberg says, "These and the former specimens were sent over in

* "On Microscopic Life in the Ocean at the South Pole," by Professor Ehrenberg, 'Annals and Magazine of Natural History' (London, 1844), vol. xiv. p. 169 *et seq.*

bottles of water. They were the same sealed bottles in which they were collected in the year 1842. In the first bottle, in which the sediment was considerable, almost every atom being a distinct siliceous organism, *Hemiaulus antarcticus* predominated. The larger bottle of the second mass had allowed the greater part to leak through the sealed cork, so that only about a quarter remained. The mass of sediment arrived in Berlin in 1844, almost all in such a condition that the author had no hesitation on considering them still alive, although they all belonged to the almost or perfectly motionless forms. The Fragillarias" (Diatoms) "predominated; these, though rarely adherent in chains, had their green ovaries mostly preserved in a distinct natural disposition: *Coscinodisci* and *Hemiaulus* also often exhibited groups of green granules in their interior. No movement."

It will be noticed that a great portion of the organisms grouped together under the designation of "Siliceous Polygastrica" are referred by other writers to the vegetable kingdom; these, although not strictly falling within the scope of the present observations, nevertheless illustrate the point under notice, namely, what ought and what ought not to be accepted as proof of vitality in the Protozoa as well as the Protophyta.

The annexed extract from a letter of Professor Ehrenberg's to Captain Maury, dated "Berlin, October 1857"*, shows that the same views continue to be upheld by that indefatigable observer. Addressing Captain Maury, he says, "In your memoir, published by the Geographical and Statistical Society of New York, I see that you have followed the judgment of the old observers, who deny the existence of stationary life at great depths, and who sustain themselves of late by the observations of Mr. Forbes. Also Mr. Bailey has of late published similar opinions. I cannot agree with this antibiotic judgment, after having put it beyond doubt that the greater part of the small calcareous carapaces is filled with small soft bodies; Mr. Bailey also speaks of his observation of these soft bodies in the *Siliceous Bacillaria*, which strengthens my own remark. That the great compression prevents putrefaction is a hypothesis; but the existence of the soft bodies is a certain observation.

"The other argument for life in the deep, which I have established, is the surprising quantity of new forms which are wanting in other parts of the sea. If

* Maury's 'Sailing Directions,' 8th edition. Washington, 1857: p. 175.

the bottom were nothing but the sediment of the troubled sea, like the fall of snow in the air, and if the biolithic curves of the bottom were nothing else than the product of the currents of the sea which heap up the flakes similarly to the glaciers, there would necessarily be much less of unknown and peculiar forms in the depths. The surface and the borders of the sea are much more productive and much more extended than the depths; hence the forms peculiar to the depths should not be perceived. The great quantity of peculiar forms and of soft bodies existing in the innumerable carapaces, accompanied by the observation of the number of unknowns, *increasing with the depth*,—these are the arguments which seem to me to hold firmly to the opinion of stationary life at the bottom of the deep sea."

It is at all times a difficult and an ungracious task to endeavour to demonstrate the fallacy of the views of others, but it becomes tenfold more so when the author of those views holds such an eminent position as Professor Ehrenberg. In the present instance no middle course is left open to me, inasmuch as, disagreeing in almost every fundamental particular regarding the nature, the structure, and the functions of the lower tribes of organisms met with in the oceanic deposits, I am compelled not only to adduce the data on which my own opinions are founded, but to show why I decline to subscribe to opinions that are diametrically opposed to them.

One of our foremost naturalists and comparative anatomists has characterized the researches of Professor Ehrenberg as "wonderful monuments of intense and unremitting labour, but at least as wonderful illustrations of what zoological and physiological reasoning should *not* be;" and has declared it to be "a matter of duty, on the part of those interested in the progress of zoology, to pronounce decidedly against the statements contained in the 'Infusionsthierchen,' so far as regards anatomical or physiological facts"*. I can only appeal to the opinions I have quoted, and the data on which they have been based, in support of the course it has thus been rendered imperative on me to pursue.

Before closing this portion of my subject, it remains for me to draw attention to the very singular fact that whilst Professor Ehrenberg, in common

* 'Annals and Magazine of Natural History,' 2nd series, vol. viii. p. 436: Professor Huxley on the genus *Thalassicolla*.

with many of the other authorities whose opinions have been cited, completely ignored the researches of Sir John Ross, published more than twenty years previously (it being distinctly stated in Professor Ehrenberg's communication to the 'Annals and Magazine of Natural History,' from which the last extracts have been made, that 190 and 270 fathoms were "the greatest depths that had" previously to 1844 "been sounded"), not one of those writers has, up to the present hour, recognized the validity of Professor Ehrenberg's reasoning with reference to the vitality of creatures belonging to the very lowest type, and therefore much less likely to be affected by conditions which they contend would prove fatal to creatures of a higher order.

Having thus placed before the reader the grounds on which naturalists have heretofore regarded the deeper abysses of the ocean as unfitted for the support of animal life, and having endeavoured to state fairly the value of the evidence adduced by the only two observers whose researches have been directed towards the establishment of an opposite view, I have now to draw attention to the physical conditions by which the geographical distribution and the duration on the earth of marine creatures are determined, and to the various influences which, in conformity with the most recent discoveries, appear to regulate their bathymetrical range.

It would be foreign to the purpose of the present inquiry to state the various arguments by which the theory of transmutability of species and the doctrine of specific centres of creation have been maintained by their respective supporters. It is sufficient to know that, commencing from an assumed period in the earth's history, no matter how remote from "the beginning," certain forms were grouped together within fixed geographical areas, each of which was already distinguished by typical characters. Were it possible to define this period, or to adopt a cotemporaneous starting-point for every group of animate forms on the surface of the globe, whence to calculate the amount of divergence or specific differentiation its several species had undergone, the task of determining which hypothesis is true and which false would be comparatively easy. But, in the absence of such a fixed point, it only remains for us to draw our inferences from well-marked modifications in the characters of well-known species, and endeavour to reconcile these modifications with such altered conditions of the earth's crust as we can prove to have accompanied them.

When we consider the changes which are continuously and yet almost imperceptibly going on in the distribution of land and sea, and bear in mind that, although the periods occupied in the completion of these are inconceivably vast, they are insignificant in comparison with epochs in the world's history anteriorly elapsed, we shall understand how gradual must be the operation of causes by which the characters of species are modified and their disappearance from the earth eventually brought about. Were it otherwise, all the individuals belonging to a species in any given zoological province would leave their remains within the narrow stratum of deposit on which they had lived. But this happens only in exceptional cases; and hence we meet with fossil remains of species extending frequently through strata of such immense thickness as to prove, in conjunction with what is known of the rate at which those strata are formed, that vast changes in the relative distribution of sea and land must have occurred before they became extinct.

Bearing this fact in mind, it is necessary to avoid the very common error of taking for granted that the ancestors of animals living at the present time under a set of recognized conditions must have lived under similar conditions since the period at which they first appeared on the earth. The fossil remains of the older extinct forms, both of animals and plants, clearly show how different must have been the condition of the earth's surface when they peopled it. But we have only to look at the changes observable during much more recent periods, in order to be satisfied that species still in existence must have passed through repeated and critical alterations in the conditions by which they were surrounded; and in such cases we might naturally expect to find structural modifications to have taken place in a greater or less degree. A time will in all probability arrive when, by a further series of changes, these existing forms will in turn become scarcer and scarcer, and then finally disappear from the earth. The extinction of certain Struthious birds is well known to have been completed within a very recent period; and although in some examples human agency has been instrumental in producing this result, there is no reason to believe that in the case of the gigantic Struthious forms of New Zealand, or in that of the Great Awk of the Arctic regions, extinction has not been consequent on natural causes. But, supposing changes on the earth's surface and climates to have been moderate in extent and duration, it is evident that creatures may have survived

conditions which, if sufficiently protracted in their operation, would have proved fatal, and that they may have received a new vital impulse, as it were, from the relapse towards those conditions which were normal,—the alternate tendency towards extinction and re-establishment having been carried on through several repetitions of these changes, and resulting in an augmented or a diminished power to become permanent, as the digression from or recurrence to the normal state assumed the preponderance.

It is to Sir Charles Lyell that we are indebted for the first clear exposition of the relation subsisting between the geographical distribution of organized beings and the "inorganic changes" which are continually taking place over the globe. So long ago as the year 1832 this all-important subject was treated by him in the original edition of his 'Principles of Geology'—a work which constitutes at once the most compendious and the most perfect record of the great physical laws which have through all time modified the exterior of the globe. To Mr. Darwin's researches much is also due—authenticated examples of specific divergence having been collected and explained by him in a manner that leaves no doubt on the mind of the facts, although his final inferences are held to be "unproven" by some, and untenable by others.

Sir Charles Lyell remarks* that, however uniform may be the action of "inorganic causes," its effect on the organic world is far from being uniform in equal periods of time in different localities. There cannot be a doubt of the correctness of this view with regard to inorganic agencies operating on land, but there is good reason for supposing that when operating at sea their results are of a far more uniform nature in like periods; for, assuming, as we are warranted in doing, that over large equal areas of globe the amount of subterranean disturbance is similar during vastly extended periods, it follows, from the much greater area of sea as compared with land, that the effects would be diffused over a much wider space, and hence sudden changes in distribution of the sea-bed would be less frequent, whilst alterations in its depth would be much more slow in their production.

"We may fairly infer," says Sir Henry De la Beche†, "that the great mass of organic remains, like the accumulation of detritus amongst which such remains

* See Lyell's 'Principles of Geology.' London, 1853: p. 691 *et seq.*

† 'Researches in Theoretical Geology,' by Sir H. De la Beche, F.R.S., &c., 1834, p. 266.

occur, was accumulated in moderate depths around coasts, and either on or around shoals at no considerable depth below the surface of the sea." The same view has been held by all subsequent writers; and this may explain, in some measure, why it has been asserted that fossil species, which extend through the greatest thickness of a deposit or series of deposits, have in all probability also commanded the widest horizontal range,—the inference being based on the supposition that, during the vast periods of elevation or subsidence which rendered a change of position necessary, littoral species, in order to endure, must have traversed successively formed zones. If by horizontal range it is meant that such species must have lived along very extended coast-lines to admit of their surmounting the obstacles which occasionally prevented the maintenance of their normal depth, the view may be regarded as correct. Otherwise it would appear that the geological range has been confounded with the geographical, inasmuch as the measure of the horizontal area over which such a fossil species may be found constitutes but the sum of an indefinite number of geographical areas to each of which it was restricted for the time being. And hence, apart from other evidence, the greatest vertical as well as the greatest horizontal range of such a species, whilst attesting its duration, affords no proof of its wide geographical distribution at any given period.

In the case of fossil deposits formed at the bed of the deep sea, however, it may be fairly assumed that the horizontal range bears a much closer relation to the actual geographical distribution of a species at any given period of its history; for, although the sea-bed may be regarded as the reflex of the land, softened down somewhat by the deposits continuously accumulating on its surface, the very nature of the conditions present yields the creature living there a much greater chance of escape from hurtful influences than pertains to littoral species. Thus the latter, in event of elevation of a coast taking place, could descend in one direction only, to maintain their special bathymetrical zone; and should a shoal or reef skirt the shore, advance in that direction would be precluded. Therefore, unless the creature were capable of enduring a change of conditions incident on removal to a higher zone, even no further elevation of the coast-line took place, the result would be fatal to it.

In the case of deep-sea forms, excepting those located in circumscribed and isolated areas, the possibility of migration to a locality at which the conditions

were favourable to life would be vastly increased; that is to say, they would have two or more directions to select from, and accordingly the risk of extinction from inorganic causes would be materially lessened; the extension of the geographical range of a species, under these circumstances, being at the same time facilitated and expedited.

In the case of marine creatures, the necessity for migration from place to place in consequence of changes which render residence in particular localities unsupportable must, for these reasons, occur much less frequently. It is also reasonable to suppose that the tendency to extinction of marine as compared with terrestrial animals, from purely "inorganic causes," must be proportionately small, inasmuch as, the ratio of land and water on the globe being as 3 to 10, terrestrial animals must be more frequently checked in migrations which might save them from extinction, by the intervention of an element they are unfitted to encounter.

Again, human agency must operate to a much smaller extent in effecting the extermination of the smaller and lower forms of the animal kingdom in the ocean than it is known to have done in the case of creatures inhabiting circumscribed areas on land, since access to their haunts is, for the most part, impossible. And further, as there is good ground for believing that, although the deepest abysses of the ocean have their living occupants, the number of individuals is in all probability very large whilst the number of tribes is proportionally small, the tendency to extinction of certain tribes by furnishing sustenance to others becomes materially reduced.

Having thus cursorily and, I fear, very imperfectly detailed the chief causes which are concerned in determining the distribution and duration of marine species, I have yet to show how they bear on the question of life in the deeper abysses of the ocean. Before proceeding with this portion of my subject, however, it is necessary that I should describe, for the information of those who will, I trust, constitute a large proportion of my readers (namely, students of marine natural history and others who may have opportunities of taking soundings), the bathymetrical distribution of both the animal and vegetable creation, down to those depths which it has heretofore been customary to regard as azoic.

The late Professor Edward Forbes was the first to point out that the various species of marine animals and plants inhabit distinct successive zones or belts, commencing with high-water mark and extending downwards, as he himself

defines them, "to the deepest abysses from which living beings have been extracted." There are four of these zones in the European seas, each of which is marked and may at once be recognized by typical organisms or groups of organisms peculiar to it and to it only. Some organisms, however, are common to all the zones, whilst others are only common to two or three.

The first or littoral zone is that which extends between tide-marks, whether the rise and fall be one foot or fifty.

The second or Laminarian zone extends from low tide-mark to a depth of about 15 fathoms, and forms the great centre of sea-weeds, "fishes, mollusks, Crustaceans, and Invertebrata of all classes, remarkable for the brightness and the variegation of the patterns of their colouring."

The third or Coralline zone reaches down to a depth of about 30 fathoms below the limit of the Laminarian zone. Here both vertebrate and invertebrate animals are abundant, but plants become scarce.

The fourth or deepest, namely, the deep-coral zone, extends towards that abyss where, to repeat Professor Forbes's words, "life is either extinguished or exhibits but a few sparks to mark its lingering presence." It may be said to reach down to a depth of from 300 to 550 fathoms in different latitudes, although, according to Forbes's observations, its limit falls short of either of these estimates*.

It will be observed that the vertical limits of each of these zones increases with the depth; so that whilst the upper has a depth of only a few feet, the lowest ranges from 100 to 300. "Specific animal forms," writes Mr. Austen, "decrease rapidly; and just as the sub-aërial zones of vegetation present us at last, as we ascend, with only such forms as lichens, so at depths of from 70 to 100 fathoms we have the obscure Nullipores as the extreme forms of marine vegetation"†.

I shall hereafter show that, at depths vastly exceeding those above alluded to, animal life is abundantly represented; and, as already stated, although the crowning evidence still remains to be elicited in the case of the Foraminifera and Polycystina (namely, vital movements after being brought up from the sea-bed), such evidence has already been elicited in the instance of creatures of a far higher order, namely, radiate animals—facts being forthcoming to prove that

* See 'The Natural History of the European Seas,' by the late Professor Edward Forbes, p. 24 *et seq.*

† Ibid. p. 189.

their normal habitation is in the deeper abysses of the ocean, whilst presumptive evidence of the vitality of the Foraminifera with which they are associated is afforded by the remains of these having been detected by me in the digestive cavities of the radiate creatures in question.

Assuming these facts then for the present, we have to modify to a considerable extent the usually received views regarding distribution and duration of species, to which attention has already been drawn.

Since we know that similar climates and conditions of the earth's surface do not necessarily involve the presence of the same kinds of organized beings, and, on the other hand, that the association of similar forms does not involve the existence of a similar climate, we are justified in supposing that animals of the same species (that is to say, originating from one specific progenitor), now living under widely different conditions as to climate, have gradually become habituated to the transition from one set of conditions to the other, during the lapse of extended periods in which alterations in the distribution of sea and land, of sufficient magnitude to have produced these climatal differences, have taken place.

But it appears to me that this inference is warranted, whether we accept the doctrine of single specific centres or that of the transmutation of species, since it is conformable with all that is known of the duration of species to believe that the period requisite to effect marked modifications in their characters is brief, in comparison with that which is included between their first appearance on earth and their final disappearance from it, and, hence, that the duration of any given form may be regarded as often extending beyond the period occupied in any single change in the distribution of land and sea. . For it is evidently unphilosophical to suppose that a species, once fairly established, should disappear from the face of the earth before it had passed through that specific life which is as essentially a law of nature as the life of the individual—and tantamount to an assertion that creation is without a purpose, and under the influence of accidental agencies.

Whatever views may be entertained regarding the origin of species, it is universally admitted that they are associated together in distinct groups, each of which is typical of the zoological province in which it occurs, in the same manner that certain species are typical of each group—the same group and the

same species never being repeated either in space or time, and the same species never appearing in two or more provinces, except as an emigrant from its genetic centre. By what laws the adaptation of particular regions for particular species is determined we have at present no means of ascertaining, inasmuch as the existence of similar climates neither involves the presence of similar species, nor is the presence of similar species necessarily associated with the existence of similar climates.

But whilst the distribution of living animals and plants has already been defined throughout the entire terrestrial portion of the globe with a close approach to accuracy, our knowledge of the distribution of the inhabitants of the ocean has been almost entirely restricted to coast-lines, and even as regards these we have no systematic information beyond European seas. The great zoological provinces of the open ocean may therefore be regarded as unexplored, save in the case of a limited number of free-floating organisms; and, as a natural consequence of the antibiotic view respecting its deeper abysses, the entire submarine provinces of life, vast and varied as they must be if life be there present at all, remain as yet a *terra incognita.*

In our endeavours to trace the distribution of the lower microscopic forms of animal and vegetable life, the difficulties are still further enhanced owing to the greatly increased liability to diffusion by accidental causes, and a large proportion of the entire series having thus become common to every portion of the globe. Nor is this world-wide dispersion confined to recent species; for, as shown by Ehrenberg, it extends to many fossil forms. Amongst the Foraminifera, living species still abound in our seas which flourished in the ancient seas of the Mesozoic period, long before any of the now living species of the higher orders of the animal kingdom had as yet made their appearance on earth. The same universality of distribution is to be observed amongst the Polycystina, and, on the vegetable side, amongst the Diatomaceæ and Desmideaceæ, although in the fossil condition the two former have not hitherto been detected so far back in time, and the latter are altogether unknown*. When the extremely minute

* It has been customary to regard certain minute spinous bodies in the Cretaceous flints as sporangial cells of Desmidiaceæ. The Rev. J. B. Reade was the first to draw attention to these bodies, in a paper published in 'The Annals of Natural History' for 1838. Subsequently they were detected by Mr. Deane in the substance of the Chalk itself, and were shrewdly surmised by him to be of animal origin (Trans. Microscop. Soc. 1849, vol. ii.). In 1851, and again in 1857, the organisms referred to

and fragile nature of the Desmidiaceæ is taken into consideration, this is hardly to be wondered at; but as regards the Polycystina and Diatomaceæ, it is far from improbable that we only fail to detect them owing to the presence, in both fresh and salt water, of substances which unite with and thus obliterate all trace of their siliceous structures. Should this surmise be correct, fossil representatives of these organisms may yet be found whensoever an ancient sea, lake, or river-bed shall present itself which has been so suddenly upheaved by subterranean force as to have been denuded of its waters before chemical combination could take place*. But, even without this additional fact, we have ample proof that the

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were detected by me in the material obtained from the stomachs of *Salpæ* in the Indian Ocean and mid-Atlantic; and although at the time regarded by me as true pelagic representatives of the Desmidiaceæ and Diatomaceæ, more recent observation has convinced me that, in the case of the former, the resemblance is one merely of form and not of structure, the Xanthidium-like bodies being distinctly of animal origin.

* Since the above observation was put in type, a short notice has appeared in the 'Geologist' for June 1862, which, in a great measure, confirms this surmise. It is there stated that, in the "hornstone nodules of the *Devonian* and *Silurian* rocks of New York, organisms similar to, and probably identical with, those which occur in the Cretaceous flints and the Chalk itself, have been detected by Professor Dana and Dr. M. C. White." As the importance of this fact is in reality far greater than at first sight appears, I subjoin an extract from a paper, detailing my reasons for doubting the vegetable origin of the organisms in question, published by me in the 'Quarterly Journal of Microscopical Science' for October 1860, "On the Siliceous Organisms found in the Digestive Cavities of the Salpæ":—

"The history of the fossil *Xanthidia* of the Cretaceous flint nodules has hitherto been beset with a most perplexing difficulty. Apart from the much-vexed question as to the manner in which the siliceous element of the nodules became aggregated into masses, so as to enshroud these structures, the occurrence of organisms, held to be strictly inhabitants of fresh water, in deposits of unquestionable marine formation, presented an ample field for discussion and conjecture. The Desmidiaceæ, of which family the Xanthidia constitute the sporangia, are thus described by Mr. Ralfs: 'All the family are inhabitants of fresh water. Mr. Thwaites, indeed, has gathered two or three species in water slightly brackish; but the same species are also found in localities remote from the sea. Certain marine objects that have been classed with the Desmidieæ have the internal matter of a brown colour, but these belong to the Diatomaceæ.'—*Ralfs*, '*British Desmidieæ*,' Introd. p. 2.

"In order, therefore, to account for their occurrence amongst purely marine deposits, it was deemed necessary to assume that they had been washed down by rivers or floods, or transported by winds from the land to the sea, where, after gradually subsiding, they became incorporated with the siliceous material in which they were found imbedded. The tough, semi-horny texture of their outer covering, and well-known power of withstanding extreme climatic changes, seemed to favour this idea of their indestructibility, even under conditions so opposed to those in which they originally lived. But the explanation was, at best, unsatisfactory.

lower the organism in the scale of being, the greater is its numerical intensity, the more universal its distribution, and the longer its duration in time,—one and all of these characteristics being dependent, not on increase of power to withstand destructive influences, but on decrease of sensibility to them.

It is well known that the geographical distribution of terrestrial life is mainly dependent on climate, that is to say, on the several agencies which modify the condition of the atmosphere and the earth's surface in different latitudes. These agencies are temperature, elevation, amount of moisture, carbonic acid and accidental gases in the atmosphere, configuration of surface, and light. If we turn to the ocean, we find that similar or at least equivalent agencies determine the distribution of the creatures that inhabit it. The following Table will serve to illustrate the relation of these agencies in the two cases, their aggregate values being empirically estimated at 1000:—

Land.		*Sea.*	
Temperature of air	400	Temperature of water	350
Elevation above sea-level Rarefaction of air	200	Aëration of ditto	300
Amount of moisture in ditto	100	Depth below surface Amount of pressure	100
Carbonic-acid gas in ditto Ammoniacal and accidental gases in ditto	50	Carbonic acid in water Saline constituents in ditto	150
Configuration and composition of surface	150	Configuration and composition of bottom	50
Light	100	Amount of light	50
Total..	1000	Total..	1000

"The discovery of two well-marked varieties of *Xanthidia*, in a recent state, amongst the alimentary contents of the *Salpæ*, was therefore fraught with no slight interest. From the condition of their endochrome it is certain they had but recently been inclosed in the cavities of these creatures; and from the situation in which they were discovered, it is equally certain that they could not have been derived from freshwater sources by any of the agencies above referred to. But whether or not these bodies are the sporangia of genuine pelagic *Desmidiaceæ*, they certainly exhibit an identity of appearance and structure with the fossil forms, too striking to admit of question. The probability, however, of their being true pelagic representatives of this family is greatly enhanced by the occurrence, in the same material, of bodies closely resembling the *Closteria*. These have only been met with sparingly, and it has been impossible, therefore, to determine their nature with certainty. But the strongest evidence in favour of their identity with the fossil *Xanthidia* is derived from their association, in the recent state, with other organisms, such as *Diatomaceæ* and *Foraminifera*, whose fossil remains, in like manner, occur associated with them in the flints. The question as to their being true sporangia of *Desmidiaceæ* becomes, therefore, of secondary importance."

Although the temperature of the ocean is much more equable than that of the atmosphere, there is good reason to believe that its waters are susceptible of climatic changes of a very important nature as regards their effects on the distribution of life. No doubt these changes are more frequent and less lasting near the surface, and hence operate more markedly on the creatures that inhabit the superficial zones; but it must be borne in mind that the very nature of the conditions, dependent as they are principally on the reciprocal action of the atmosphere and water, presupposes a different set of conditions as the depth increases, and, hence, that a limit is speedily attained, beyond which the sudden advance of creatures living above or below becomes at once injurious to them. It is only when we regard the comparatively insignificant stratum of water to which animal existence has heretofore been supposed to be circumscribed, that the capacity of the ocean for the maintenance of life falls short of that which we are in the habit of ascribing to the atmosphere; and the moment it is recognized as a fact that animal life, instead of being confined to the few hundred superficial fathoms, reaches down into the deeper abysses, it becomes evident that the vertical limits above and below the sea-level are in reality almost coequal.

Although any attempt to construct a bathymetrical plan of the deeper zoological zones of the ocean would at present be premature, the data in our possession are nevertheless sufficient to warrant the inference that, where a few living forms have been detected, numerous others exist; and, accordingly, the construction of such a plan may be regarded merely as a question of time and scientific research. There may be blank areas on the sea-bed, as there are unquestionably blank and uninhabitable areas of land; but, again, assuming that the conditions are not of a nature to render life impossible, we are warranted in taking for granted that these areas are no greater in the one case than in the other. "The history of our own seas and of all seas," observes Mr. Godwin-Austen, "teaches us that there is a law of proportion in the classes and orders of the living things that dwell there, and that the presence of one form is safe ground of inference as to the co-existence of countless others"*. Higher authority than this we could not have; for, although the doctrine thus enunciated bears reference to the distribution of life apart from that of the deep sea, it must be admitted that the same general application of the laws of nature, for which Mr. Austen is so

* 'Natural History of the European Seas,' p. 247.

staunch an advocate, is admissible in the present instance the moment the existence of one living form in the depths of the ocean is incontrovertibly proved.

Although temperature is the most important element in determining the climate of a region, its independent influence (that is to say, the temperature of a locality as due to its geographical position only) is subject to great modification from collateral causes—namely, the degree of elevation above the sea-level, the amount of humidity present in the atmosphere, the prevailing winds, and the surface-configuration. These all act reciprocally on each other, and in certain cases produce such alterations in the climate within the same area as would result from a complete change of geographical situation. Thus, at a given height on the mountain-ranges of equatorial countries we find a region of perpetual congelation, and in descending from that elevation towards the sea-level there occurs every variety of temperature, from arctic cold to tropical heat; the various zones being distinctly marked by the character of the vegetation they are adapted to support.

If we turn to the ocean, we find its climates are dependent, in like manner, on causes which modify its temperature, namely, the temperature of the superincumbent air, the prevailing currents, and, to a limited extent, the configuration of its bed,—the currents, like the winds on land, serving to equalize the heat and prevent stagnation; whilst, in shallow waters, the nature of the bottom serves to modify the force and direction of the currents, and, both in shallow and in the deeper portions, it exercises a powerful influence in determining the kind and the distribution of the creatures that dwell upon it.

It is well known that in every latitude, commencing from the confines of that portion of the polar area within which the temperature is said never to rise above freezing-point* and extending to the equator, there exists a belt of atmosphere of varying thickness, which marks the oscillation of the line of perpetual congelation during summer and winter. It is obvious that the upper boundary of

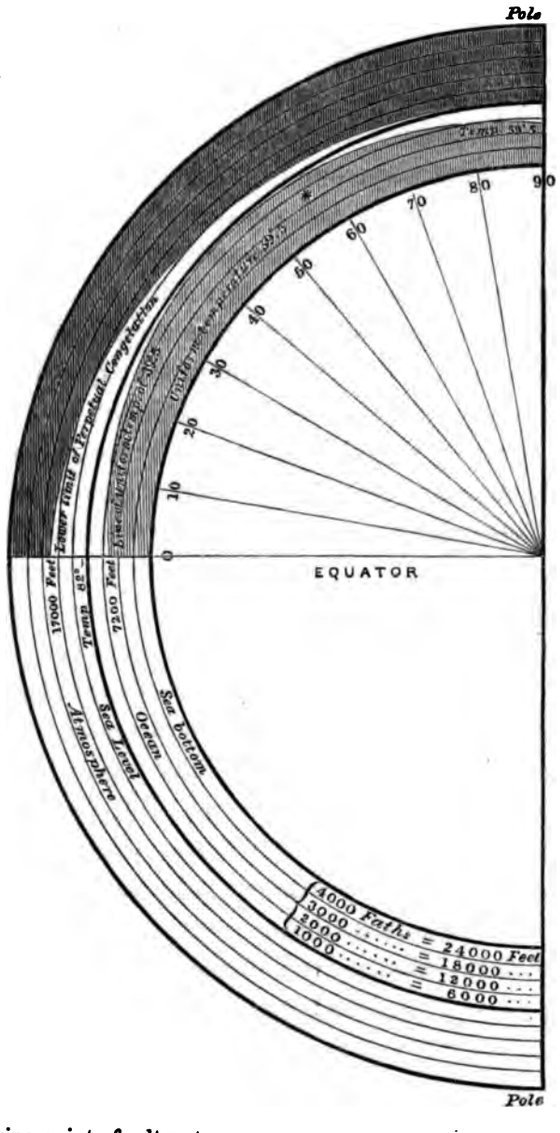
* It has been customary to assume that at about the 75th degree of latitude the line of perpetual congelation is coincident with the sea-level; but, according to Sir John Richardson, this does not accord with observation in the Northern Hemisphere, there being "no Arctic district to which man has as yet penetrated in which there is a permanent covering of snow through any wide extent of low country."—See 'Arctic Searching Expedition,' by Sir J. Richardson, C.B., F.R.S. London, 1851: vol. ii. p. 213.

this belt, if traced along any given meridian, would be coincident with the sea-level in the first of these positions, whilst it would attain its maximum elevation above the sea-level in the last; or, taking the mean of such oscillation, that an arc of a circle might be described somewhat nearer to the level of the sea than the upper margin of the belt, which would denote the mean annual altitude of the snow-line.

Inasmuch as the temperatures of the ocean and atmosphere are in a great measure mutually dependent on each other, and both derive their heat from the same sources, we might naturally expect to find a line of uniform temperature in the sea which would bear some evident relation to that in the atmosphere; and such is the case, although the space above and below these respective boundary-lines is subject to widely different laws. Thus, in the ocean we meet with an isothermal curve, which attains its maximum depth below the surface at the equator, and is coincident with the sea-level (that is to say, rises to the surface) in lat. 56° 62′, dipping down again as it advances from that point to the pole. Although this isothermal curve is liable to slight oscillation from similar causes that bring about the oscillation of the aërial belt, the variation is so small as to be hardly perceptible; and accordingly, a series of two larger and two smaller arcs, described along any given meridian, will represent the line of uniform temperature of the sea with sufficient accuracy for present purposes. But whilst the temperature of the atmosphere beyond the line of perpetual congelation goes on gradually decreasing*, that of the water below the isothermal line remains constant to the bottom. Were it not for the operation of the law on which the latter phenomenon depends, the entire ocean would long since have become solidified and both sea and land rendered unfit for the habitation of living organisms. Unlike other bodies which expand and become lighter with every rise in temperature, water attains its maximum density, not under the lowest degree of cold, but at 39°·5 Fahr.; and consequently, as soon as the superficial layer of sea is cooled down towards this degree, it descends and allows a fresh portion to ascend and be in turn cooled. This process is continued until the whole upper stratum is reduced in temperature to 39°·5, when, instead of contracting further, it begins to expand and get lighter than the water beneath, floats on it, becomes

* According to M. Fourier, the temperature of the ethereal regions has been estimated at —50° F., whilst M. Pouillet estimates it at —220° Fahr. (Somerville's 'Physical Geography,' vol. ii. p. 33.)

further cooled down, and at 28½°* is converted into ice. In this state, having arrived at its maximum lightness, its position remains unchanged; and being a bad conductor of heat, the circulation between the superficial and lower strata ceases and thereby prevents the congelation of the entire body of water, which would take place did the density increase indefinitely with the decrease of temperature so as to permit of congelation commencing from the bottom instead of the surface of the sea.



Thus, under the operation of an apparently exceptional law, the equilibrium of the oceanic circulation is maintained; for whilst at the equator the mean temperature of the surface-layer of water, which is 82°, gradually decreases until at a depth of 1200 fathoms it becomes stationary at 39°·5 Fahr., and retains that temperature to the bottom, within the polar regions, and extending to lat. 56° 25′ in either hemisphere, the temperature increases from the surface downwards to the isothermal line, beyond which it remains uniform as in the former case. Hence in lat. 56° 25′, the temperature is uniform the whole way from the surface to the bottom, and, as has been found by observation, about lat. 70° the isothermal line occurs at 750 fathoms below the surface. The annexed diagram will give a general

* The freezing-point of salt water.

idea of these two isothermal curves, and also of the temperature of the water from surface to bottom, in the locality at which the Star-fishes were captured,—a most important fact, to which I shall have to refer particularly hereafter.

Although a certain amount of heat is constantly being given off from the interior of the earth, its quantity is so small as to exercise no perceptible influence on climate. On the other hand, the quantity of heat annually received from the sun, and upon which the temperature of the earth's surface may be said entirely to depend, is so great that, were an equal amount not radiated into space, the temperature would very speedily become insupportable. The quantities given off from the first of these sources, and received through the last, have been computed by M. Peltiers and M. Elie de Beaumont with reference to their capability for dissolving a certain bulk of ice,—it being computed that the quantity of central heat which reaches the surface of the earth in the course of a year would suffice to melt a layer of ice a quarter of an inch in thickness, covering the entire globe, whereas the quantity of heat received directly from the sun in the course of a single year would suffice, in a like period, to melt a layer of ice 46 feet in thickness, covering the same area. But, notwithstanding the amount of solar heat thus imparted to the earth, its influence does not extend deeper under the surface than from 60 to 90 feet; whilst below this point there is a regular increase of temperature, arising from the earth's central heat, amounting to 1° for every 55 feet of descent.

It follows that, at any given depth of sea-bottom, the heat emanating from the earth's centre is the same as would occur at the same depth of solid crust, but that, owing to the rapidity with which the temperature communicated is diffused through the entire mass, all accumulation of heat is prevented. Hence, although the line of uniform temperature in the ocean is unquestionably modified to a certain extent by the heat received from below, its depth below the surface is entirely regulated by the amount of solar heat absorbed, coupled with the amount of radiation, incident on the degree of latitude. In shallow seas or along coast-lines, where the disturbing action of tides, currents, and inequalities of the bottom is felt, as a matter of course, the isothermal line vanishes, and the temperature of the various vertical zones of water is determined by a new set of conditions.

For these reasons, whilst temperature may justly be regarded as the most important element in regulating the distribution of life within the bathymetrical limits hitherto insisted on as extreme, it becomes highly probable that, in those profounder abysses, extending from a quarter of a mile below the surface to depths yet unfathomed by the sounding-machine, this uniformity constitutes the pre-eminent condition of animal existence, and that a number of creatures formed to live under it will yet be found equally distributed throughout the vast area of the sea-bed.

It has long since been ascertained that the number of types, as also of genera and species, of the animal and vegetable kingdoms materially diminish as we advance from equatorial to polar regions; and hence this decrease cannot be regarded otherwise than as indicative of dependence on reduction of temperature. Until a little more is known of the deep-sea fauna, it would be injudicious to speculate on the relative numerical proportion of its members in different latitudes. But we are warranted in assuming, even from the scanty data already at our command, when taken in conjunction with the established uniformity of climate prevalent through the length and breadth of the deep-sea bed, that no such marked variation exists as that just referred to in the case of the terrestrial and the superficial marine fauna. And further, if it be legitimate to estimate the profusion of deep-sea forms generally by the number of individuals belonging to the same species which were brought up from a single spot of the sea-bed, there is every reason to believe that it falls short in no degree of that observable amongst species frequenting the superficial zones.

It is a very significant fact, and one the importance of which was fully appreciated by Edward Forbes and Professor Löven, that the greatest profusion of typical Invertebrata is to be met with, not in the superficial, but in the deeper zones of the Arctic and Boreal provinces, and, moreover, that the downward range of the four bathymetrical zones is much more extended than in the Celtic or Lusitanian provinces. Want of time and opportunity unfortunately prevented me from carrying out my intended series of observations on the bathymetrical range of the Greenland Invertebrata; and, as noted in my diary, my dredgings at Goodhaab were altogether confined to the fiords near the anchorage, where the depth of water did not exceed 200 fathoms. But even this limited experience left no doubt on my mind that the abundance of some of the forms met

with falls far short of that which occurs throughout the next 100 or 200 fathoms, inasmuch as the number of individuals regularly increased down to the greatest depth reached by the dredge. On the other hand, there was a distinct decrease both of animal and vegetable life in that stratum of surface-water which corresponds to the littoral and laminarian zones of the southern provinces. In the shallow channels which, here and there, form the communication between adjoining fiords, the various species were scantily represented; and from the immense masses of decayed Algæ interspersed amongst those in the full vigour of Greenland summer growth, it is evident that the alternation of seasons, either directly by change of temperature or indirectly by the production of so much fresh water, must exercise a more hurtful effect than it does where the climate is milder and more equable. In the fiords themselves, both of Labrador and Greenland, where the marginal depth ranges at once from 10 to 20 fathoms, the growth of Algæ is more or less absent near the surface, and only commences at the point at which in other latitudes it usually ceases.

The subjoined is the general result of my few dredgings at Goodhaab:—

From 50 *to* 100 *fathoms.*

CRUSTACEA.

Hyas arenaria.

MOLLUSCA.

Hiatella arctica.
Cardium Grœnlandicum.
Pecten islandicum.
—— pectinatum.
Mytilus edulis.
Trophon Fabricii.
—— Grunneri.
Margarita striata.
Volutomitra Grœnlandica.
Astarte elliptica.

ANNELIDA.

Pectinaria.
Spio.
Cirratulus.
Syllis.
Terebella.

COTTIDÆ.

Cottus glacialis (Rich.).

From 100 *to* 200 *fathoms.*

CRUSTACEA.

Hippolyte polaris.
Gammarus arcticus.
Caprella linearis (on Algæ).

MOLLUSCA.

Acmea testudinalis.
Chiton marmoreus.
Natica Grœnlandica.
Lima Subauriculata (East Coast in sounding).

TUNICATA.

Boltenia picta, n. s.?

ECHINODERMATA.

Echinus sphæra.
—— neglecta.
Ophiocoma bellis.
—— granulata.
—— Goodsiri.
Ophiura texturata.
Solaster papposa.

ANNELIDA.

Serpula contortuplicata.
Terebella (several species).
Spirorbis communis.

Connecting the increased downward range of the organisms here named with the prevailing temperature at the surface and the subsidence proved to have taken place along the western coast of Greenland, it appears difficult to regard them otherwise than as cause and effect, and as indicating the first step towards that tolerance of extreme conditions which we have hitherto been taught to consider impossible.

Again, according to Mr. M'Andrew, there is a distinct tendency of northern forms to inhabit deeper zones as they approach the equator,—a very remarkable example having been adduced by that gentleman in the distribution of the Testacea at Mogadore, on the West Coast of Africa. Thus, out of 110 species, about one-half of which range north as far as our own coasts, 88 were found at depths not exceeding 30 fathoms, and amongst these were all the characteristic African and Lusitanian species; whilst out of 22 species obtained at depths varying from 35 to 50 fathoms, all but six were well-known British shells*.

Excessive cold is undoubtedly the chief antibiotic of the polar and sub-arctic regions. The thick belt of ice which hangs about the shores of Greenland and Labrador for at least eight months out of every twelve, and which, on its breaking up, clears the rock-surfaces of a great portion of their fixed animal and vegetable forms, fully accounts for the barren aspect of the Littoral and Laminarian zones, except in the shallow channels above alluded to, and along projecting spits where the inclination is so gradual as to prevent the close approach of the heavy ice. Both near Goodhaab and Julianshaab, and also on the Labrador shores, the entire absence of every trace of animal or vegetable structure along the more exposed tracts was very remarkable; and, in addition to this, the rocks themselves were worn down and polished to a much greater extent than could have been effected by wave-action or weathering alone. There was no indication, however, of the increase of littoral animals or plants having been permanently arrested, or of actual death having ensued, from any degree of cold short of protracted congelation. The healthy condition of the fixed organisms obtained from a depth in the fiords just below the limit of annual congelation, and the absence of the disintegrated masses of Algæ which must have been observable had they been involved in it, attest this fact; and, as already stated, a very remarkable

* See 'Natural History of the European Seas,' p. 227.

example of the endurance of cold was afforded by the Medusidæ and Beroïdæ, which were seen, during calm weather in the fiords, disporting themselves in the closest proximity to the ice-masses. Nevertheless, it is evident that there is a bound to this endurance for each kind of organism, inasmuch as a number of dead specimens of the beautiful little *Spirialis* were brought up, off Cape Farewell, from a depth of 1177 fathoms, the soft parts and fragile shells of which were in such a perfect state of preservation as to render it evident they had perished amongst the ice and subsided to the bottom after death; whilst the extremely rare appearance of *Spirialis* and the more common Gymnosomatous Pteropods at the surface, during the entire period of our cruise in the Greenland seas, clearly pointed to the abnormal influences that had there presented themselves.

The effect of extreme cold, or indeed of any degree of cold greatly in excess of that which is habitually borne by animals and plants inhabiting different latitudes, first retards growth, then restricts it, and, if sufficiently protracted, causes death. The same may be said regarding the effects of extreme heat; but there is good ground for the belief that creatures indigenous to a cold region can endure with impunity much greater vicissitudes of temperature than those indigenous to a warm region; that is to say, a creature living in the sea where its temperature is 40° Fahr. could sustain an increase of 40° with greater safety than a creature living where the temperature is 80° could sustain a decrease of a like extent. Or, to put another hypothetical case, if an arctic and a tropical species were respectively placed under the conditions most congenial to them, and then subjected, the one to a great and sudden increase, the other to as great and sudden a decrease of temperature, the arctic species would, in all probability, suffer the least.

But the most important point in favour of the arctic over the tropical species remains to be noticed, and it is as follows:—Assuming that no arctic species, under any circumstances, is subject to a wider range of temperature than that between the freezing-point of salt water (namely, 28½° Fahr.) and the mean temperature of the ocean (namely, 39°·5), it is obvious that, if accidentally transported to any distant region, it can at all times command the latter temperature by migration to a deeper zone; and accordingly, if we put pressure out of the question (as I shall immediately endeavour to show we can do without infringing a single condition of marine existence), there is no bathymetrical

limit to animal life in the ocean beyond that depending on the presence of the necessary food. But in the event of a tropical species being accidentally transported, say to the Boreal province, it follows that if it survive at all, it can only do so by accommodating itself to a change of temperature very nearly three times as great as in the former example. These are undoubtedly extreme cases, but they are nevertheless possible ones; and I desire to draw attention to the very remarkable inference that may be deduced from them, namely, that whereas migration from the equatorial towards the polar regions is beset with extraordinary difficulty, and hence tends towards that concentration of surface-life which is known to occur in the former of these, migration from the polar regions towards the equatorial presents hardly any obstacle. Why then, it will be demanded, do we not find arctic forms in tropical waters? Because, from the very nature of the conditions, the migration must take place along the deep homothermal sea—that great highway extending from pole to pole, which is for ever closed to human gaze, but may, nevertheless, be penetrated by human intelligence*.

If the arguments in support of what has been termed the antibiotic view be carefully scrutinized, they will be found to rest almost exclusively on the negative evidence afforded by the enormous pressure present at the bottom of the ocean. For, although the decrease of light, of aëration, and of the ordinary sources of food was regarded as contra-indicative of "any kind of life analogous to that with which we are acquainted," apart from the operation of pressure, there is nothing in these conditions to render life impossible. It had not been taken into consideration that the more recently devised appliances for bringing up the material from the sea-bed were singularly unfitted to secure any living creature larger or more specialized in structure than the Rhizopod, even if present, and, hence, that the mere circumstance of failure to capture creatures of higher type afforded no proof whatever of their non-existence; whilst by a retrogressive kind of reasoning it was maintained that the Rhizopod could not

* To Sir James Ross is due the merit of having been the first to catch a glimpse of the relation subsisting between the belt of uniform temperature, so admirably explored by him in the Antarctic seas, and the migration of deep-sea species. For, although he based his inferences, as already stated, on observations made during the Voyage of Discovery to Baffin's Bay in 1819, and which were regarded by naturalists (without a single exception, as far as I am aware) as unsupported by sufficient evidence, his faith in those observations was as natural as the incredulity of the scientific world was illiberal.

live at extreme depths, simply because it exhibits no trace of active vitality after being dragged from a normal to an abnormal element.

Again, false analogies were advanced to show what would be the effect of the stupendous pressure known to prevail at the bottom of the ocean on creatures constituted to exist under a totally different series of conditions. Thus, the collapse of the air-bladder in some fishes, the disembowelment of others, the inconvenience experienced by persons when carried down only a few fathoms in the diving-bell, the long and arduous training undergone by the pearl-fisher, the hackneyed experiments on submerged logs of wood and legs of mutton, and, lastly, the fact that limestone could be fused under the pressure present without parting with its carbonic acid, have one and all been more or less emphatically dwelt on and handed down from writer to writer, until, like a troubled dream which the mind finds it difficult to shake off, a fictitious belief in the analogy of the cases was engendered.

To air-breathing terrestrial animals the diminution of pressure accompanying increase of elevation above the sea-level stands in the same relation as the increase of pressure attendant on augmented depth does to water-breathing creatures in the ocean. Every one is aware that, at the level of the sea, the pressure of the atmospheric column upon every square inch of surface is equal to 14½ lbs., and, hence, that the pressure distributed over the body of an average-sized man amounts to about 33,600 lbs., or nearly 15 tons. Now, since at an elevation of 18,480 feet the weight of the superincumbent column is reduced one-half, according to the law of the expansion of gases, these 14½ lbs. would be reduced to 7¼—a degree of rarefication which is constantly undergone by travellers without danger and but a very moderate degree of inconvenience if gradually encountered, and not greatly in excess of that present in the great mountain-ranges of tropical America and Asia, where we meet with flourishing cities and villages, surrounded by abundant cultivation*. It is obvious, therefore, that the human frame, endowed as it is with an unparalleled degree of complexity and susceptibility to external conditions, may nevertheless thrive for any length of time in an atmosphere so rarefied that the too abrupt transition to it from the sea-level would be attended with serious if not fatal consequences.

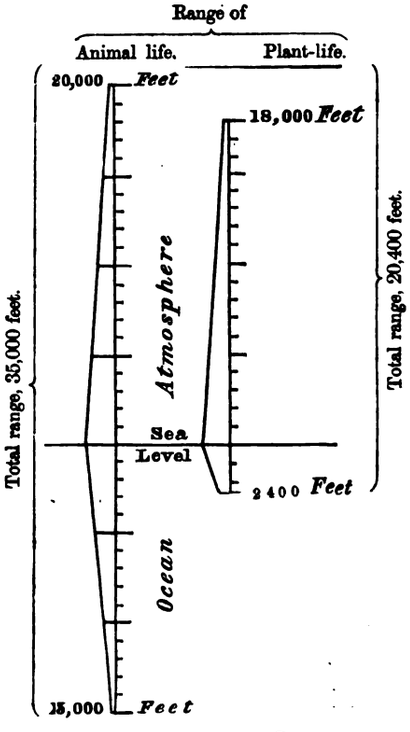
* Quito is situated at an elevation of 10,000 ft. above the sea-level. The Potosi mines, on the table-land of Bolivia, occur at 16,000 ft. Some passes in the Himalayah have an elevation of 20,000 ft.

In the Condor of the Andes we have a notable example of the power possessed by the Vultures to accommodate themselves to rapid changes of atmospheric pressure. Humboldt describes this bird as soaring for protracted periods at an elevation of 18,000 feet; and it is known to live and breed at from 10,000 to 15,000 feet. I have myself seen the common Eagle of the Himalayas soaring for hours at very little short of the same height. Fishes abound in mountain-lakes up to 13,000 feet; whilst there is no elevation, short of the limit of perpetual snow, at which the microscopic forms both of the animal and vegetable kingdoms do not habitually live; and it is highly probable that, in the latter case, it is the diminution of temperature, and not the increase of rarefaction of the atmosphere, which determines their ascending limit.

Again, plants flourish at very great heights. In Chili and Peru, wheat grows abundantly up to 13,000 feet; in Mexico, the limit of trees and shrubs is said to be 13,000 feet also; whilst in the Himalayas, as recorded by Captain Gerard, the *Genista*, a kind of broom, is to be met with at from 17,000 to 18,000 feet above the level of the sea.

Assuming then 18,000 feet to be the extreme vertical limit of plant-life above the sea-level, and 400 fathoms, or 2400 feet, as its extreme limit below, and, at a moderate estimate, 2500 fathoms, or 15,000 feet, as the limit in depth of animal existence in the ocean, and 20,000 feet as the extreme altitude which any animal can encounter above the sea-level, we obtain a total vertical range for plants of 20,400 feet, and for animals of 35,000 feet. Hence the ratios are as follows:—

Total vertical range, above and below sea-level, of plants as compared with animals, nearly .	5 to 7
Vertical range of terrestrial as compared with marine animals	4 to 3
Vertical range of terrestrial as compared with marine plants	15 to 2
Vertical range of terrestrial plants, as compared with terrestrial animals	9 to 10
Vertical range of oceanic plants, as compared with oceanic animals, about	1 to 6



It has been pointed out, at a previous page, that temperature is the most important as well as the most uniformly operating condition in the distribution of terrestrial animal life, and, moreover, that it exerts an equivalent influence on marine life. When, however, we estimate its effects on the bathymetrical distribution of animals and plants in the ocean, we find them to be extremely unequal; for, whereas marine organisms are now known to exist at a depth of at least 15,000 feet below the surface, no vegetable structures with which we are acquainted have been met with in a living state lower down than 2400 feet. But, although it would be premature, with our present knowledge of the deep-sea bed, to assert that this limit may not be considerably exceeded, there is every reason to believe that, beyond that depth, a boundary is rapidly attained at which a condition absolutely essential to plant-life in the ocean fails, and hence renders its downward extension impossible. That condition is light.

The two next conditions are elevation above and below the sea-level. A small representative value is assigned to these, because, although associated with the hitherto subtle and unexplained influences which at times determine the appearance of certain creatures in certain strata of the atmosphere, and also of certain creatures in certain bathymetrical zones of the ocean, there is no ground for the supposition that, *per se*, they exercise any effect of the kind. What these influences may be, there are at present no data whereupon to form a conjecture, since they have hitherto been recognized only by their results. It is clear, however, that they are not due to temperature, since the same temperature at different periods does not produce similar results on the organisms in question. In like manner, they are not attributable to rarefaction or pressure, since under a similar amount of pressure or rarefaction the same phenomena do not necessarily occur. It is possible, and even probable, as regards the ocean, that they may be in some way connected with the amount of light present, inasmuch as light exercises a marked influence on the appearance and disappearance of life near the surface of the ocean, and of certain animal forms in given strata of the atmosphere. But even here we meet with the same inconstancy of action as in the former cases, as shall be shown hereafter—several new and highly interesting facts tending to show that, whilst a certain quantity of light is absolutely indispensable to the growth and colour of certain plants, it is

by no means essential either to the growth or to the colour of the animal forms of the ocean.

It is obvious that rarefaction of the air, in the main, implies elevation above the sea, and attendant decrease of temperature; but it also involves something more, since we find certain birds, as for example, the Tropic-bird (*Phaëton*), almost invariably flying at a great elevation, even in the calmest weather. Here temperature can exert no influence; for, were the object to be attained a reduction of temperature, the bird would naturally frequent cooler latitudes, further removed from the equator than those it is usually found in. From the structure of the head and beak, the "Tropic-bird" is clearly an animal-feeder, preying, like most birds that frequent the open ocean, on minute Animalcules, Crustaceans, and Molluscoids. The selection of great heights, therefore, cannot be held to be due to the search for necessary food, but to some instinctive preference for a less dense atmosphere. In like manner, the Govinda Kite, both in the mountains and plains of India, remains, for many hours daily, at very great elevations in the atmosphere. The search for food cannot be the incentive in this instance, since these birds soar as often after their meal as before it, and frequently under circumstances which render it but too palpable that food is in superabundance.

Some idea may be formed of the vastness of the pressure prevalent at great depths from the fact (which may be readily proved by recourse to a few figures) that at a depth of a mile it amounts to 2640 lbs., or 160 atmospheres, on every square inch; whilst at 4000 fathoms, which is equivalent to about $4\frac{1}{2}$ miles, it amounts to 750 atmospheres; and water, which ranks amongst the least compressible of all known compounds, would be compressed, at a depth of twenty miles, to $\frac{1}{20}$th of its original volume*. Computations of this kind have long been in vogue; and, as before stated, the extraordinary nature of the conditions they involve has led to a sort of unquestioning belief that, where they are present, all life is impossible. The chief fallacy has consisted in the introduction of cases which are parallel in no essential particular. Thus, the effects of this stupendous pressure has been viewed in relation to its effects on fishes having closed air-bladders, or, at all events, bladders only capable of being cleared of their contents by a very slow process; and, as a matter of course, but one

* See 'Physical Geography,' by Mrs. Somerville, vol. i. p. 325.

inference could be arrived at, namely, that such swimming-bladders would collapse.

Again, pieces of wood retained for an hour or two at a depth of a thousand fathoms are said to have become so increased in density as to "sink like stones." Captain Scoresby relates an example of a boat having been dragged down by a whale to such a vast depth that the wood of which it was formed sank like a stone, not only immediately after its recovery from the sea, but "for a year afterwards." Here, then, it would appear that the whale must have descended as deep as the boat, or probably deeper, inasmuch as the latter was attached to it by the whale-line and harpoon. Other instances have at various times been recorded of harpooned whales having dived down vertically to immense depths, and, in some cases, having been killed by coming into forcible contact with the bottom!

But, notwithstanding the vast muscular power possessed by the gigantic Cetaceans, and the momentum attained by their bodies when diving with extreme speed, we should hardly be justified in looking to them for evidence tending to prove that life can be maintained at depths exceeding 500 fathoms. This will perhaps be rendered more apparent when it is recollected that the whale is not constituted to live at any great depth, and that its specific gravity is such as to be in equilibrium with the surrounding element almost immediately below the surface. Hence, even at the moderate depth of 500 fathoms, its body would be exposed to such a degree of compression as would at once paralyse, if not destroy, life. Thus, if we take the case of a medium-sized whale, say 50 feet long, and with an average diameter of 10 feet, the total pressure on the surface of the body would amount to upwards of 11,000 tons. It is supposed that the peculiar conformation of the Cetacean skin, throughout the substance of which the blubber is secreted, enables the creature to sustain a degree of pressure that would otherwise be intolerable—a pressure stated as "sometimes amounting to a ton upon every square inch"*. But, inasmuch as the whole of the observations on the depths to which whales have been supposed to penetrate are based on the quantity of line run out, and its direction on entering the water, it is much more likely that, as in the case of soundings taken where deep-seated currents prevail, the direction is changed from a vertical to a horizontal one,

* See Professor Carpenter's 'Zoology' (London, 1857: 2 vols.), vol. i. p. 239.

long before the extreme depths were reached at which these tremendous pressures exist*.

In the case of pieces of wood and meat, and corked bottles containing air, which have been sent down to great depths in order to demonstrate the effects of pressure, it is evident that precisely those conditions are present which are never to be met with in creatures constituted to live under it. In short, they prove too much; for they prove clearly that, in defiance of all obstacles, a state of equilibrium is rapidly engendered between the interior and the exterior of the wood, the mutton, and the bottles, and that whensoever this takes place no further change is experienced. If suddenly submerged, that is to say, before the pressure has time to overcome the resistance of the cellular and fibrous tissues of the two first and of the cork employed in the last, diminution of bulk and consequent compression of the structure must inevitably result; but, on the other hand, if the submergence be gradual, the diminution in bulk is by no means a necessary consequence, and the change brought about is a simple displacement of a lighter medium by a heavier, according to a well-known law of fluids. The example so often cited of the cork being at first forced inwards, and subsequently redriven into the neck of the bottle so as to close it as effectually as before, clearly shows that its cellular tissue has undergone compression and redilatation. Hence these experiments can only be regarded as illustrating phenomena which are not confined to extreme depths in the ocean, but may be seen in operation in a modified degree in every piece of floating organic matter around us.

The faculty possessed by some ground-living fishes of accommodating themselves, in certain localities, to depths greatly in excess of those usually frequented by them is very remarkable. Thus, several of the Cod tribe have a vertical range from 10 to 200 or even 250 fathoms, whilst a large number of species inhabit depths ranging from 10 to 100 fathoms. But, according to M. Pouillet†, certain fishes have been obtained by him from a depth of 550 fathoms, that is,

* Since the operation of getting an "up-and-down" sounding is attended with considerable difficulty, even when undertaken with a sinker of the shape best fitted to descend vertically, and a line little thicker than an ordinary pencil, it may readily be imagined how vastly the chances of an incorrect estimate, both with regard to depth and direction, must be increased, where the line employed is three-quarters of an inch thick, and a wounded monster is fast to the end of it.

† 'Elémens de Physique Expérimentale,' tom. i. p. 187.

3300 feet, where the pressure amounts to more than 100 atmospheres. Now, it is quite as difficult, in reality, to believe that a creature constituted to live near the surface, where the pressure does not exceed two or three atmospheres, could adapt itself to sustain a pressure of 100 atmospheres, as it is to conceive that a fish ordinarily living under this amount could sustain five times as much more pressure; for the moment it is admitted that the same species may accommodate itself to widely varying depths, the principle of progressive adaptation comes into play, and we are warranted in assuming that very widely differing degrees of pressure and other collateral conditions may be encountered, provided the transition from one to the other be sufficiently gradual, and, further, that the more simple the organism, the more fitted will it be to undergo them with impunity.

It has already been shown that the human frame is able to undergo a diminution of nearly one-half the normal atmospheric pressure present at the sea-level, if gradually encountered. Now, although the degree of tolerance involved in this change of conditions seems to bear no comparison with that which we suppose must be necessary to enable an animal to bear several hundred times the normal pressure it is used to, there is a very important difference between the primary conditions existing in the two cases, which renders the comparatively slight reduction of atmospheric pressure much more determinate in its effects on the one than the vastly increased amount of pressure on the other. Thus, assuming the solids, fluids, and gaseous contents of the human frame to be in equilibrium under the normal pressure at the sea-level, and that each of these portions of the body is subject to a different rate of expansion and contraction, it follows that this state of equilibrium must become more and more disturbed as the atmospheric condition becomes more abnormal. Hence we can readily account for those painful sensations which are experienced in suddenly ascending to great elevations, or descending, as in the diving-bell, through depths which engender even greater and much more sudden modifications.

On the other hand, in the case of all water-breathing creatures, inasmuch as there are no gaseous contents present, and the circulating fluid is of the same or very nearly the same specific gravity as the surrounding medium, and every portion of the structure is completely pervious to fluids, either by its porosity or through endosmotic action, the state of equilibrium remains undisturbed; and,

as already stated, no injury accrues, provided the transition from one degree of pressure to the other be sufficiently gradual.

In the case of creatures generated at great depths, and migrating to higher zones, the same law would apply, time being the essential element in rendering the transition practicable and safe to the creature. The Ophiocomæ obtained from a depth of 1260 fathoms (nearly a mile and a half) were not only alive when they emerged from the water, but continued to move their rays freely for a quarter of an hour afterwards. It is to be regretted that, in my anxiety to preserve the specimens, no effort was made to keep some of them alive in their natural element. But, even in the absence of further evidence, the one great fact remains, that these starfishes retained their vitality for nearly an hour, during which period they passed through every gradation of pressure ranging from a ton and a half on the square inch to only 15 lbs. Accordingly, since there are no grounds for supposing that star-fishes, or any other creatures constituted to live in the ocean, could undergo a transition from a high to a low degree of pressure with greater safety than one from a low to a high degree, and the abrupt change of conditions was borne in the present case without producing instant death, it is but fair to assume that, under a sufficiently gradual transition, *any* given amount of pressure might become supportable.

Respiration may be regarded as the primary vital function of every animate organism. Without it the independent life of the individual, whether animal or plant, cannot have a beginning; and on its permanent interruption, existence ceases. In so far as we know, and judging from all analogy, this law holds good in the lowest as well as the highest order of being. The mechanism of respiration may be more complex in one than in the other; but, so far from the phenomena being wonderful in proportion as they are complicated, the opposite of this proposition is correct, and we find it difficult to comprehend how the humblest tribes, both of the animal and vegetable kingdoms, in the absence of anything like specialized structure, can nevertheless bring about the same results. As is well known, in the case of air-breathing creatures the act of respiration consists in the absorption into the blood of oxygen derived from the atmosphere, and the exhalation of carbonic-acid gas—the interchange taking place by means of the lungs, and the required effect being produced on the blood. In the case

of what are termed water-breathing creatures, the phenomena are essentially the same, inasmuch as the supply of oxygen, though not derived immediately from the atmosphere, is obtained from a certain quantity of atmospheric air present under all circumstances in waters fitted to be the habitation of organized beings.

Any of the causes which materially diminish the supply of atmospheric air tend to impair vital energy, and, if sufficiently protracted, to destroy life. Thus, fishes and all other aquatic animals die almost immediately if placed in water which has been deprived of its air by boiling.

Under these circumstances, the due aëration of the waters of the ocean constitutes one of the most important conditions of marine life *; and it becomes a question of the highest interest to trace the process whereby it is brought about in these deep abysses which would seem, at first sight, to be completely beyond the pale of atmospheric influence.

It is still a disputed point whether the oxygen and nitrogen of the atmosphere enter into chemical combination, or simply constitute a mechanical mixture. Whichever view is correct, the union takes place in determinate proportions —namely, one volume of oxygen to four volumes of nitrogen; and these remain constant under every degree of rarefaction and compression, and at all temperatures short of combustion.

Although the above may be regarded as the normal composition of atmospheric air, it is certain that the present order of life on the earth could not be maintained were these the sole elements present. Even animal life, which, for anything that we know to the contrary, depends on the respiration of air thus constituted, would speedily become extinct, inasmuch as it is dependent on the previous manifestation of plant-life, and plants require for their respiration and growth carbonic acid, aqueous moisture, and ammonia. Now, by a wondrous system of compensation, the gases evolved during the processes of animal respiration, combustion, and fermentation, are exactly those which minister to the respiration and nutrition of plants; whilst plants, in their turn, exhale the gas which is essential to the life of animals, and consume those elements which, if permitted

* It is necessary to state that aëration is made secondary to temperature, inasmuch as under the existing order of nature it is impossible to imagine the proportion of air present in the waters of the ocean so altered as to endanger the life of creatures inhabiting them; but it is far from being so to conceive the occurrence of changes of temperature which might not only endanger but destroy it.

to accumulate in the atmosphere to an indefinite extent, would render it unfit for the support of all organized beings whatever.

If we turn to the ocean, we may find the conditions modified but not changed. For whilst atmospheric air, as already pointed out, is indispensable to the respiration of water-breathing (or, in other words, marine) animals, carbonic acid is equally indispensable for that of marine plants. It has been customary to regard carbonic acid as present in sea-water in comparatively minute quantity, and, as if in apology for this minuteness, to maintain that it could not "possibly be wanting in a fluid in which a far greater number of animals breathe than on land"*. I shall hereafter endeavour to prove that the supply of this gas demanded for the ocean is infinitely in excess of the quantity usually ascribed to it, and that, whilst it is derived by absorption from the atmosphere, the actual quantity poured forth into the atmosphere during the processes of animal respiration, combustion, and fermentation could be reduced by no other means than this absorption to the small proportional amount discoverable by analysis at any single period.

In the same manner that the aqueous vapour present in the atmosphere is merely held in suspension, so are the gaseous bodies present in sea-water merely held in solution; that is to say, in neither instance does a chemical combination occur under ordinary pressure. Water absorbs a certain quantity of all gases, some, however, in much larger quantity than others. Thus, whilst it absorbs nearly volume for volume of carbonic acid under ordinary pressure, it can only take up about $\frac{1}{29}$th of its volume of oxygen and $\frac{1}{40}$th of nitrogen. When the two latter gases occur in the shape of atmospheric air, the quantities are slightly modified—rather more oxygen, and rather less nitrogen, being absorbed. But, under an increase of pressure, the proportion of gaseous matter taken up by water is very greatly increased, as may readily be understood when it is borne in mind that fluids are nearly incompressible even under extreme pressure, whereas gases are easily compressible, and that the relative volumes of the gas absorbed and the fluid absorbing are acted on in widely different degrees.

The mode in which the solution of atmospheric air in sea-water is brought about is but imperfectly understood. It is probable that the agitation of the surface resulting from the action of winds and currents assists in effecting

* Bischof, vol. i. p. 116.

the admixture; but since we know that the operation of these causes extends but a little way below the surface, and that, far within the limits to which animal life has heretofore been supposed to range, their action is altogether arrested, it is evident that the absorption of air must be mainly dependent on some constant property of fluid and gaseous matter unconnected with these agencies.

Since the tendency of fluids to absorb gaseous bodies is constant under all circumstances, although, as already stated, the quantity they are capable of appropriating increases with the pressure, it follows that, the deeper the stratum of water, the greater must be the amount of gaseous matter held in solution by it. In illustration of the manner in which a column of sea-water becomes saturated with its complement of gaseous matter, let us suppose atmosphere and ocean to be brought into contact for the first time, and the process of absorption to be commencing. As soon as the superficial stratum of water received its full charge, it would transfer a portion to the stratum immediately below it. This stratum, when fully charged, would in like method transfer a portion to the succeeding one, receiving a fresh supply from the stratum above, and so on through the entire series; whilst in order to meet the demand thus continually increasing from below, an uninterrupted absorption would be carried on at the surface, the lowest stratum being the first saturated; whilst the highest would serve as a channel of transmission for the whole of those below it, and be the last to arrive at the point of saturation, notwithstanding that its gaseous contents are the smallest in quantity.

Were the pressure equable throughout the entire vertical range of the column, the transmission of gaseous matter from above downwards would only proceed until the quantity absorbed in equal volumes of water was similar at the surface and at the bottom. But, inasmuch as the pressure increases with the depth, and the quantity of gaseous matter absorbed is in a direct ratio to the pressure, it is evident that the operation must be protracted until each stratum of water has received, through the entire series of strata above it, the quantity absorbable in virtue of the pressure it is subject to. On this being accomplished, but not till then, every portion of the column would be in equilibrium with the portions adjacent to it, and, accordingly, all further abstraction of gaseous matter from the atmosphere would cease, in the absence of any expenditure taking place from below.

It may, perhaps, be urged against this theory, that, instead of remaining in the state of equilibrium indicated, the tendency of gaseous matter would be to rise

and escape at the surface; but, inasmuch as the capacity to absorb a given quantity of such matter, under a given degree of pressure, admits of no variation, and it is clear that the affinity of the fluid for the gas is more powerful than any other counteracting influence, since otherwise absorption could not take place even at the immediate surface of the sea, there are no circumstances under which the evolution of the gaseous matter could occur. The example of ascending thermal springs charged with gases and salts is by no means a parallel one; for in these the column is circumscribed within solid walls, and each successive zone or stratum of water, in ascending, carries along with it its gaseous contents; and, as a necessary consequence of removal from a greater to a smaller degree of pressure, the disengagement of gas takes place. In the ocean there are no ascending currents of the kind; but even if there were, the conditions would be dissimilar, inasmuch as each portion of water ascending would instantly be replaced by fresh portions poured in under the same degree of pressure, and therefore charged with the same amount of gaseous matter. Hence, unless it can be shown that increase of pressure does not enable water to absorb a greater quantity of gaseous matter, it follows that the latter must always bear a direct ratio to the former.

It is far from my meaning to assert that the quantities of oxygen, nitrogen, and carbonic-acid gases absorbed by sea-water at any given depth would equal the quantity of one of these gases absorbed by the same volume of water under the same pressure, supposing no other gaseous or saline constituent to be present in it, but only that some increase of absorbent capacity must take place for every increase of pressure, and, hence, that the increased quantity of one of these gases absorbed at the base of the column of sea-water, or at any point intermediate between the sea-bed and the surface, would bear a definite ratio to that of the other gases absorbed along with it. It is well known that, in order to ensure the greatest amount of absorption by a liquid, it is essential to free it, in the first place, by boiling or otherwise, of all other gaseous matter, and, moreover, that the absorbent power is greatly diminished by the presence of saline substances in solution. Now sea-water contains both other gases and as much as 3·527 of saline substances in solution, and it is highly probable that the proportion of the latter increases with the depth. Therefore we should naturally expect to find the increase of absorption moderate in comparison with what would take place were the water in a state of purity.

According to the most recent analyses, the mean amount of carbonic acid in the atmosphere is estimated at about 1 part in 1000 by weight. In the various notices of the gas it has been customary to state that this proportion, although unexpectedly small, is nevertheless sufficient to supply the entire vegetable kingdom with the carbon of which their solid tissues is composed. If my theory be well founded, this 1 part in 1000 does not represent the quantity originally present in the atmosphere, but only the residue which remains after supplying the requirements of the ocean and plant-life; in other words, it is the floating deposit destined to meet current expenditure, the amount being kept up by the processes already referred to.

According to Vogel, in 10,000 parts by weight of sea-water from the Mediterranean and the Atlantic there were present 1·1 and 2·23 parts, respectively, of carbonic acid—a quantity extremely small, and yet declared to be sufficient, not only to retain the whole of the carbonate of lime actually present in sea-water in solution, but five times as much. According to some valuable experiments conducted on board the French ship 'Bonité,' the fact has been clearly established that the quantities of atmospheric air, and more particularly of carbonic-acid gas, increase with the depth. The analyses, as cited by M. Bischof†, are so striking, and exercise such an important bearing on all questions relating to the deep-sea deposits, that I am induced to quote them in detail.

Time and place.	Depth in Paris feet.	Gas in 100 volumes of water.	Gases.			Sum of oxygen and carbonic acid.
			Oxygen.	Carbonic acid.	Nitrogen.	
1836. South Sea.	0	2·09	0·13	0·22	1·74	0·35
	349	2·23	0·23	0·40	1·58	0·63
1837. Bay of Bengal	0	1·98	0·11	0·28	1·59	0·39
	997	3·04	0·10	1·77	1·17	0·87
1837. Bay of Bengal	0	1·91	0·12	0·25	1·54	0·37
	1495	2·43	0·14	0·73	1·56	0·87
1837. Indian Ocean	0	1·85	0·18	0·23	1·44	0·41
	2243	2·75	0·27	0·96	1·52	1·23
1837. Atlantic Ocean. . . .	1994	2·04	0·08	0·59	1·37	0·67

* The specimen of surface-water was lost in this example.

† See 'Chemical and Physical Geology,' by Gustav Bischof. Translated from the German, and published by the Cavendish Society, vol. i. p. 114.

In opposition to the views advanced by me with regard to the increase of atmospheric air in the waters of the ocean with the increase of depth, I would draw attention to the experiments of M. Biot on the gaseous contents of the swimming-bladders of fishes*. It is stated by Sir Henry De la Beche, on the authority of M. Biot, that whereas the swimming-bladders of fishes caught near the surface were filled, not with pure atmospheric air, as might have been expected, but with nearly pure nitrogen, the swimming-bladders of such as were brought up from a depth of 500 fathoms were filled with oxygen and nitrogen in the proportion of 9 of the former to 1 of the latter—the conclusion arrived at from these facts being that there was a difficulty in obtaining nitrogen at great depths, whilst it was procurable in abundance near the surface, and hence that atmospheric air was more plentiful in the latter than in the former situation.

It is worthy of note, however, that these proportions do not tally with the fact that in a given volume of water, under ordinary pressure, the quantity of oxygen is rather greater, and that of nitrogen rather less, than is compatible with the ratios borne by these two gases to each other when in combination as atmospheric air. For, since the normal ratio of oxygen to nitrogen is very nearly as 1 to 4, and the relative quantities of these gases absorbed by water are as 3 to 2, and assuming with Sir H. De la Beche that the quantity of atmospheric air present decreases with the depth, we should expect to find more oxygen present in the swimming-bladder of the fish taken from the surface than in that taken from deep water. It should be borne in mind, moreover, that the swimming-bladder is in no way connected with respiration, and that it only serves to regulate the specific gravity of the fish; and hence the secretion, when at the greater depth, of that gas which is considerably heavier than the other is precisely what might be looked for when the object to be attained is the maintenance of equilibrium with the surrounding medium. But it has already been stated that the normal ratios of the two gases, as they exist in atmospheric air, are modified to a very considerable extent when they are held in solution by water, oxygen being taken up in larger quantity, and nitrogen in less, and the former of these gases constituting $\frac{3}{5}$ths of the water itself. Hence assuming, as is the case, that the gaseous contents, whatever they may be, of the swimming-bladder are secreted through the circulation, and not imbibed directly into its

* 'Researches in Theoretical Geology,' by Sir H. De la Beche, p. 229.

cavity, we are warranted in supposing that the quantity of oxygen found in it is larger in deep water than at the surface, owing to that gas being more essential to vital action, being present in greater abundance, and approaching more closely to the specific gravity of the surrounding medium than nitrogen. This view is borne out, moreover, by the 'Bonité' analyses, which show the tendency of the nitrogen to decrease with the depth.

There is another very remarkable property of gases which demands notice, although it is impossible, in the present state of our knowledge, to say how far this property may operate in modifying the combinations of sea-water and its various ingredients—namely, their liquefaction under great pressure. It has been shown that, although the degree of pressure necessary to produce the liquefaction of a given gas is constant at the same temperature, as the temperature decreases, so does the amount of pressure requisite to produce the effect diminish. Amongst the elementary gases, chlorine and cyanogen liquefy under the smallest amount of pressure, and at nearly ordinary temperatures. Oxygen, on the other hand, which is so refractory as to resist the extreme pressure it has heretofore been subjected to, when combined with an equal volume of the vapour of sulphur, as sulphurous-acid gas, becomes liquid at a temperature of 45° Fahr. under a pressure of only two atmospheres. In the same manner hydrogen, which in its separate state proves equally refractory, on being mixed with one-third of its volume of nitrogen so as to constitute ammoniacal gas, becomes liquid under a pressure of about six and a half atmospheres, at 50° Fahr.; whilst, by a remarkable change of properties, chlorine, which alone is readily liquefiable, if united with an equal volume of hydrogen requires a pressure of forty atmospheres; and hydrogen and oxygen, both of which gases in their separate state resist all pressure that has been applied to them, when combined to form water continue liquid under a pressure considerably below that of a single atmosphere. Lastly, carbonic-acid gas, which, at a temperature of 32° Fahr., requires thirty-six atmospheres to cause it to become liquid, at 14° Fahr. only requires twenty-seven—a degree of pressure far short of that it is subject to in the lower zones of the sea.

It is probable that the saline and mineral substances present in sea-water exercise a much more marked effect on the formation of the organic deposits of the deeper zones of the ocean than has been admitted under the antibiotic view

so often referred to. From the nature of the difficulties by which the inquiry is surrounded, not only is the chief portion of our knowledge regarding the deep-sea bed rather of a theoretical than a practical kind, but, unfortunately, it must long continue to be so. It is doubly expedient, therefore, to test this knowledge by the light of every fact that science or accident may throw in our way. Thus, notwithstanding all that has been achieved by chemistry and mineralogy, it still remains an open question whether the great limestone strata were precipitated from waters holding the mineral in solution, or whether the separation of the calcareous matter was a vital act involved in the construction of the shells of creatures holding the lowest rank in the scale of being. In like manner we are not in a position to state definitely the manner in which the siliceous concretions of the Chalk and the Carboniferous limestone were produced. Few persons now-a-days regard the calcareous deposits as having resulted from chemical, or the siliceous concretions from mechanical action; but, although the presence of the shells of the Foraminifera in immense profusion in some limestones supports the view that the animals to which they belonged effected the separation in question, there is no such proof forthcoming in the case of the altered limestones. If we examine the siliceous concretions, our perplexities increase rather than diminish; for whilst remains of siliceous-shelled organisms are to be met with in them, it is very remarkable that they do not belong to the family of siliceous-shelled Rhizopods which, next to the Foraminifera, are most largely represented at the bed of the ocean, namely, the Polycystina, and there is no authenticated example, up to the present period, of a Polycystine shell having been detected in a flint. From the nature of the hydro-silicates, we could hardly expect to find the forms of siliceous organisms preserved; hence it is possible that the mineral atoms of the Polycystina have become merged, as it were, into the substance of the masses. But, since we constantly detect siliceous spicules of sponges, which have not yielded to disintegration though similarly formed, it is difficult to reconcile the apparent anomaly. If we regard the concretions as principally made up of sponge-spicules, the case is but little altered; for the pseudomorphs of the calcareous shells of the Foraminifera are plentiful in their substance, and indicate that the conditions under which they were formed and silicified were such as might have been shared by the testaceous Rhizopods generally.

Under these circumstances it may not be out of place to review, as far as the limited data permit, the conditions under which the most important constituents of sea-water present themselves at great depths.

According to Bischof*, the total quantity of saline matter present in water from the Pacific, Atlantic, and German Oceans (as deduced from the analyses of Bibra) amounts to 3·527 per cent.; whereas the several ingredients occur in the following proportions:—

Chloride of sodium	75·786
Chloride of magnesium	9·159
Chloride of calcium	3·657
Bromide of sodium	1·184
Sulphate of lime	4·617
Sulphate of magnesia	5·597
	100·000

It will be seen, on reference to this table, that carbonate of lime and silica, the materials which enter so very largely into the formation of the shells and hard parts of the marine Invertebrata, are omitted. This is the more remarkable since the geological phenomena involved in the presence of these substances in sea-water may justly be regarded as amongst the most important and wonderful with which we are acquainted. For, although carbonate of lime and silica occur in proportions which appear small when compared with the mass of the ocean, they are nevertheless as essential to the existence of marine organisms of every kind as the carbonic-acid gas which is present in the atmosphere in still more minute quantity is essential to terrestrial plant-life,—the solid structure of the former being composed of carbonate of lime, of the latter of carbon. In both cases, moreover, the demand and supply of the material are balanced with such unerring nicety, that the failure of either one or the other could not take place without altogether disturbing some of the existing conditions of the globe.

It is stated by Bischof† that the vast quantity of carbonate of lime brought down to the sea by rivers, and the uninterrupted formation of the shells of testaceous animals, are of themselves *primâ facie* evidence of the presence of carbonate of lime, and that "the carbonic acid contained in sea-water will constantly dissolve carbonate of lime when present at the bottom"; whilst the fact of "the water being so far below its point of saturation as regards carbonate of lime can

* 'Chemical and Physical Geology,' vol. i. p. 379. † Ibid. p. 109.

only depend on the constant separation of the carbonate by testaceous animals." It is also mentioned, on the authority of Dr. Davy, that carbonate of lime occurs chiefly along coast-lines, and that it was only detected to the extent of 1 part in 10,000 in water from Carlisle Bay, Barbadoes, whilst in the neighbourhood of the volcanic island of Fayal the quantity was so small as to be barely discernible, and in the open sea between the West Indies and Europe it was altogether absent! Forchhammer, on the other hand, detected it in all sea-water.

The specimens of water analyzed by Bibra were obtained at a depth of only a few feet below the surface, with a single exception in which the water was brought up from 70 fathoms. Since, in the absence of any distinct statement to that effect, it is improbable that the specimens analyzed by Dr. Davy were obtained from great depths, or indeed elsewhere than at the surface, his observations only show that the carbonate of lime met with in the superficial stratum of water is derived principally from terrestrial sources; and that at a distance from coast-lines, in volcanic regions where the limestone-rocks are either wanting or covered by igneous deposit, or in the open ocean where the depth is too great to allow of any supply of the carbonate being furnished from lime held in solution or calcareous deposits at the bottom, it is entirely absent.

According to M. Bischof, water containing only one-tenth of the quantity necessary for saturation can dissolve as much carbonate of lime as if it were saturated; but since the quantity of carbonic acid present in sea-water is sufficient to dissolve five times as much carbonate of lime as is to be found in it, M. Bischof infers that its maintenance at a point so far below that of saturation must be due to the constant abstraction of carbonate of lime by testaceous creatures. He further states that since water saturated with carbonic acid is capable of dissolving only 0·1 per cent. of carbonate of lime, and under ordinary atmospheric pressure water contains its own volume of carbonic acid, a saturated solution "would contain 0·2 per cent. by weight, or ten times as much as is necessary for the solution of carbonate of lime to saturation." And, lastly, he argues that water saturated with carbonic-acid gas, even under high pressure, cannot dissolve more carbonate, because, if it did so, ascending springs would deposit their carbonate of lime, and choke up their channels, the moment the ascending stream became subject to a diminished degree of pressure *.

* 'Chemical and Physical Geology,' vol. iii. p. 171.

In stating the reasons why the gaseous contents of a column of sea-water cannot be discharged at the surface, I endeavoured to show that no analogy exists between the phenomena and those observable in ascending thermal springs in which a constant discharge takes place. If my views are correct, it is obvious that the arguments apply as forcibly to the saline as to the gaseous contents, since the same law which prevents the escape of the gaseous matter contained in each succeeding stratum will enable each to retain in solution its full complement of saline matter, so long as saline bases are supplied to the ocean.

Analyses of water taken from different latitudes and seas show that the quantities of saline ingredients vary from local causes. Thus, it has been found that in the neighbourhood of the equator, where rain-fall and evaporation are both excessive, they counterbalance each other, and the specific gravity of the surface-water and the proportion of solid matter undergo but trifling modification; but in sub-arctic regions, where the accession of fresh water is excessive during one season of the year, and evaporation at no time takes place to any great extent, the effect is much more conspicuous. The admixture of fresh water with that of the sea takes place gradually, owing to the inferior specific gravity of the former, but its influence extends to considerable depths. It is of the greatest importance, therefore, that water obtained from these latitudes for analytical purposes should not be taken from the surface, and that we should look to the deep circulation of the ocean for that equable diffusion of its various constituents on which the equilibrium and permanence of the whole depend.

It is worthy of remark that the calcareous deposits now forming over a large portion of the Atlantic and probably of all great sea-beds occur generally at great distances from coast-lines, and always in deep water; whereas coral-reefs, which derive their calcareous matter from the same source, are said to be formed in shallow water, although, through the subsidence of the sea-bed, these bases often extend to vast depths, and the reefs themselves may occur in what is now mid-ocean. Of the rate of growth of coral-reefs very little is known beyond the fact of its being extremely gradual. Of that of the Foraminiferous deposits nothing of a definite character has as yet been ascertained. Accordingly we are not in a position to declare whether the demand for carbonate of lime, in a given time, is greater in the superincumbent water of the coral-reef or the Foraminiferous deposit. But, assuming the demand to be equal in equal periods,

it is difficult to account satisfactorily for the presence of carbonate of lime in the shallow waters near coast-lines, and its entire absence at the surface of the open ocean, unless we admit that the quantity of the salt increases with the depth, and that the lowest stratum of water is that in which the conditions most favourable to the growth of the Foraminiferous shell are present.

Again, since the quantity of carbonic acid present in sea-water increases with the depth (as proved by the Bonité analyses), and the loose nature of the upper layer of the Foraminiferous deposit makes it pre-eminently liable to be acted on by a solvent, it is not improbable that a portion of carbonate of lime may be redissolved on the spot irrespectively of pressure, and that any deficiency in the supply may be made good, either by the quantity redissolved, or an increased quantity brought round by the deep oceanic circulation. If these views are correct, it is obvious that the rate at which the increase of the deep-sea calcareous deposits takes place depends entirely on the rate at which carbonate of lime can be poured into the ocean by rivers, since no new deposits could be built up, did the separation of carbonate of lime from the water holding it in solution (which is essential to the growth of the shells) and the re-solution of the dead shells counterbalance each other.

Taking all these circumstances into consideration, it appears probable that the demand for carbonate of lime at the bottom of the sea is limited only by the supply; for, inasmuch as the quantity of calcareous matter introduced by rivers is so great that, in the absence of an unceasing drain upon it by calcareous-shelled creatures, its waters would very speedily become saturated and give rise to chemical separation, and since no such separation has been found to take place (in our own day at least), and the average amount of carbonic acid is not found to decrease, it is evident that, through the increase of the calcareous-shelled organisms, the quantity of carbonate of lime brought down in solution to the deeper zones of the ocean must be altogether disposed of.

But, apart from the reasons which render the chemical separation of carbonate of lime from water holding it in solution improbable, it may be mentioned that there is no example amongst the North-Atlantic soundings, nor, so far as I am aware, amongst any of the recorded soundings taken in other portions of the ocean, of a recent deposit of lime having been met with such as would result from supersaturation alone. On the other hand, there is abundant proof of a

portion of the mechanically formed calcareous deposits being at times re-dissolved by water holding carbonic acid in solution, inasmuch as the vast amount of minute amorphous particles almost invariably present is traceable to no other source than the disintegrated animal portion of the shells left behind after the re-separation of the carbonate of lime.

According to the analyses of Forchhammer*, silica (or silicic acid) was found in all sea-water examined by him, the greatest quantity being 0·3 in 10,000 parts of water. In its pure state it is insoluble in water, but yields to water containing carbonic acid. In this respect, the conditions favourable to the presence of carbonate of lime in the ocean are also favourable to that of silica. With the alkalies silica forms soluble salts, called silicates, which enter very largely into the composition of rocks; whilst, like carbonate of lime, it is constantly being conveyed to the sea by rivers, where it furnishes material for the mineral portion of Sponges, of the Polycystina with their allies, and the marine species of the Diatomaceæ.

Although the whole of these organisms (excepting sponges, which are composite) far exceed the Foraminifera in minuteness, they nevertheless constitute a considerable per-centage of some of the oceanic deposits. As is well known, extensive strata have been found in Europe, in Africa, and America, which are almost exclusively composed of the siliceous remains of the Diatomaceæ; whilst in some parts of America deposits occur of a mixed character, that is to say, in which the calcareous and the siliceous remains are associated in nearly equal proportions. It is a remarkable fact that all siliceous deposits, such as those of Bilin, the Berg Mehl, and Tripoli, which consist almost entirely of a few well-marked species that flourished in the immediate locality, are of fresh-water origin and never occur in the ocean; whereas in oceanic deposits, although the siliceous forms may predominate, they are never unmixed with calcareous or other mineral matter. Again, in those marine deposits in which the species of Diatomaceæ are sufficiently abundant and well marked to indicate that they had lived in the immediate locality, it may be taken for granted either that the water was shallow or that the deposit was formed along a coast-line, since no Diatomaceæ live at greater depths than from 400 to 500 fathoms. In the deep-sea beds, when Diatomaceæ occur, the characters of the species, their variety, and their limited

* Bischof, vol. i. p. 109.

numbers at once show that they had been drifted from distant shallows, or were free-floating surface forms which had subsided to the bottom after death.

Whilst, as yet, we have no positive proof that the Polycystina live at extreme depths, it is a very significant circumstance that the large assemblages of these organisms hitherto met with in such a recent state as to indicate vitality occur in deep water, and that the forms taken alive at the immediate surface of the ocean in some latitudes are sufficiently distinct to prove that the same species do not occur at the surface and at the bottom without undergoing marked modification. On the other hand, there is reason to believe that some of the siliceous organisms met with in a living condition at the surface of the open ocean cannot live at any great depth, and that, from some peculiarity in molecular composition, the siliceous portion of their structure yields to the solvent power of the water. Thus the Acanthemetrina, a small group of organisms with siliceous frameworks of extreme symmetry and of such characteristic shape as to be readily distinguishable, occur in tolerable profusion in tropical and sub-tropical latitudes; but, strange to say, not a trace of their siliceous remains is to be found either in recent or fossil oceanic deposits.

The Barbadoes and other Polycystine earths have a calcareous basis derived from the same source and produced through the same organic agency as the pure calcareous deposits of the deep-sea bed; and, if we may judge from the composition of such Polycystine deposits as have heretofore been brought up by the sounding-machine, it would seem that all partake of the same character.

The character of the pure Diatomaceous earths of the Pliocene and Post-pliocene periods clearly denotes a difference in the chemical constitution of fresh- and salt-water deposits, which is of the highest importance as affording a means of determining in which of these it may have been formed, supposing the characters of the species to be uncertain; for, whereas the terrestrial species of Diatomaceæ are to be met with in water in which carbonate of lime is not necessarily present, there are no circumstances under which the marine species of Diatomaceæ and the Polycystina (all of which are oceanic) are to be met with in water devoid of that salt*.

* A systematic chemical analysis of the entire series of soundings hitherto obtained would in all probability throw a great deal of light on the geological phenomena of the globe, and, were the means forthcoming, it might very easily be accomplished.

Assuming, then, that carbonate of lime and silica are always present in sea-water, that carbonic acid increases in quantity with the depth, and that the solvent power of water as regards these two substances is due to the presence of this acid—that, on the deep-sea bed, in localities where carbonate of lime is said to occur in such minute proportions at the surface as to be inappreciable even by chemical tests, vast calcareous deposits are continuously being formed—lastly, assuming that the increase of testaceous creatures stands in a direct relation to the supply of the material of which their hard parts are composed *, we are unavoidably led to the inference that pressure, so far from restricting animal life to the higher zones of the ocean, may be regarded as one of the conditions most essential to its existence at extreme depths.

In addition to the substances already enumerated as present in sea-water, there are a few others which occur in still more minute quantities, or under such subtle combinations as to have led to their being omitted in most analyses. Regarding these, it is only necessary to state that iodine, fluorine, and phosphoric acid are detected, the first in marine plants, the second in sea-water itself, and the third in all organic remains as well as sea-water.

Of the conditions which determine the distribution of certain tribes of animals in shallow water, the composition and configuration of the bottom is one of the most important. Thus, rocky surfaces and sandy, gravelly, or muddy bottoms have each their special inhabitants, whose structure, taken in conjunction with the kinds of vegetable growth to be met with, induces them to select the localities best suited to them. There is no reason to suppose that the instinctive tendency to select certain descriptions of sea-bed in preference to others is less powerfully manifested or obeyed by creatures which live at great depths. For although we are warranted in assuming that the general character of the deep-sea bed is much more equable than that of shallower regions, there is ample evidence afforded by the soundings to show that the universal layer of soft deposit which has been declared by some writers to envelope its surface is very far from being constant, and that no more fatal mistake can be committed than to take for granted that mountain-ridges, abrupt precipices, and serrated rocks do not present themselves even where volcanic disturbance is unknown.

* The soft parts of these organisms consist of "sarcode," a proteine-compound the elements of which, oxygen, hydrogen, nitrogen, and carbon, are present in water.

It is obvious that deposit cannot take place universally over the bed of the ocean in the absence of a universal depositing-agency. Now, no such agency exists, but, on the contrary, there is clear proof that all the great calcareous deposits are of a local character; and, from what has been already said regarding the composition of sea-water at all depths and in all latitudes, it is evident that this local character is not attributable to a deficiency of calcareous material in the water, but to the absence (for reasons as yet beyond our comprehension) of the organisms by whom the separation of the material from its chemical combinations is effected.

The last condition which bears on the distribution of marine life is light,—or (paradoxical as it may appear) that total absence of light which has been regarded by philosophers and poets alike, from time immemorial, as characteristic of the Deep.

Although light can hardly be said to exert any material effect on the geographical range of marine species, it constitutes an important element in determining their bathymetrical limits within the superficial zones of the ocean. For, notwithstanding it is the essential condition of vision, and it is impossible to conceive that eyes should have been bestowed on creatures for any other purpose than to see, we must bear in mind that the instinctive and well-marked preference for particular degrees of light manifested not only by creatures wholly destitute of visual organs, but by the vegetable kingdom in general, points to some more subtle sense than that of sight, and proves that its exercise may not necessarily be dependent on the light-giving rays of the solar spectrum.

We cannot tell why light affects different creatures in different ways; but its varying influence is far too decided and constant to escape notice. Thus we find certain forms living under the full glare of day, others avoiding it; some indifferent to every degree of luminous influence, others susceptible to the slightest. But, whatever the mode in which these idiosyncrasies manifest themselves, they pervade all the individuals of the same species, and we simply recognize the fact without knowing why or how it is brought about.

Again, although it has never been directly asserted that light is essential to animal existence, such a view has been in some measure fostered by the promulgation of two axioms,—namely, that light is essential to vegetation, and that animal life is dependent on the previous manifestation of vegetable life. Both of these

axioms are undoubtedly true in the case of terrestrial organisms; but the last is wholly unsupported as regards the lowest orders of creatures inhabiting the sea; for not only does every trace of light become finally extinguished at a depth comparatively speaking insignificant, but at a point considerably short of that at which some of the most highly organized littoral species habitually live. Thus, it is supposed that at 700 feet below the surface the realm of total darkness commences; and yet we know that many creatures indigenous to the deep-coral zone, and more especially certain fishes, enjoy a downward range of from three to five times that depth—that is to say, 2000 feet beyond the reach of the most attenuated sunbeam.

But whilst animal life has recently been shown to be present in vast abundance along the deep bed of the ocean, no vegetable life of any kind analogous to that with which we are acquainted has hitherto been discovered in a similar position. Vegetable structures unquestionably occur, and at times in considerable profusion; but there is no reliable evidence to show that these have lived elsewhere than near the surface. On the contrary, the appearance of the soft parts, in such as have been raised from depths exceeding 500 fathoms, indicates a molecular constitution differing materially from that observable in similar organisms which have been taken alive in shallow water. All analogy teaches us that plants cannot live in the absence of light. Under its influence the absorption of carbonic acid goes on, and the evolution of oxygen *. In default of it, a reverse process is set up. Light exerts no influence of this kind on animals; but, as already stated, since all terrestrial animals are ultimately dependent on vegetables for their food, and vegetables are thus shown to be dependent on light for their principal vital function, we are driven to the admission that ultimately light is essential to terrestrial animals. In the sea, the conditions under which plants respire are still unchanged. Light is essential to the absorption of carbonic acid and the evolution of oxygen. Even in the case of the lowest protophyte, this fact admits of demonstration; and it must be remembered that the vegetable forms met with in the deep-sea deposits belong exclusively to the latter class. Their occurrence

* It is certain that the organs of respiration of plants are confined to their green surfaces. Humboldt is stated to have found "a species of sea-weed of a bright-green tint, *although* it had grown at a depth of 190 feet," where it was computed no more than $\frac{1}{1500}$th part of the solar rays could penetrate. (See 'Manual of Physiology,' Professor Carpenter, p. 57.)

at extreme depths in a living condition would, therefore, involve the introduction of an exceptional law, for which there is no kind of precedent.

It is one of the most important offices of plants to purify the atmosphere of the element which would be poisonous to animals were it allowed to accumulate. How then, it may be asked, are the densely peopled waters of the ocean purified of the same poisonous element, if vegetation and light cease at the same limit; and under what other conditions than exceptional ones can marine animal life be maintained without the previous manifestation of vegetable life, as must be the case if it exists at extreme depths?

The answer to the first of these questions is obvious. The waters of the ocean seize on the carbonic acid exhaled by animals, and, as already shown when discussing the saline constitution of sea-water, the quantity of carbonate of lime present is sufficient to convert so much of it into a non-poisonous compound that the remainder is as innocuous as the carbonic-acid gas invariably present in the atmosphere. On the other hand, the indispensable oxygen is principally derived from the atmospheric air which has been absorbed by the water, the portion of it exhaled by marine plants being unimportant in comparison with the area and mass of the ocean.

I readily admit the difficulty of furnishing a solution to the second question, without appealing to a process of nutrition for which there is no acknowledged precedent. At the same time I submit that in the majority of the marine Protozoa—as, for instance, in the Foraminifera, Polycystina, Acanthometræ, Thalassicollidæ, and Spongidæ—there is much stronger ground for supposing that the process referred to is that by which nutrition is effected, than that complex functions of a kind analogous to those observable in creatures endowed with specialized organs, should be performed, by the simplest order of beings with which we are acquainted, in the absence of anything approaching to specialized structure. This subject will be more fully discussed in another portion of this work: at present it is only necessary to state that no exceptional law is invoked, but, on the contrary, that the proof of these organisms being endowed with a power to convert inorganic elements for their own nutrition rests on the undisputed power which they possess of separating carbonate of lime or silica from waters holding these substances in solution. In other words, if it can be shown that these organisms are able to produce a chemical separation of inorganic

elements in order to construct their shells, we are warranted in supposing they may also apply the elements not needed for that purpose to the nutrition of their soft parts; especially since the remaining elements are those which, when united, constitute the proteine-compound of which their soft parts are invariably composed. We may endeavour to establish a definite line of demarcation between the two great kingdoms of nature; but if we unbiassedly examine the life-history of the simplest forms on either side—as, for example, a cell of *Collosphæra* and a cell of *Navicula*—we shall find ourselves reduced to the admission that the vaunted boundary-line is empirical. If this be admitted, the grand distinction between the animal and the plant is destroyed—at least in the lowest tribes—and we discern in the liberation of a portion of the oxygen and carbon of the carbonic acid, of the hydrogen of the water, and the nitrogen of the atmospheric air, a vital act heretofore regarded as characteristic only of the vegetable kingdom. In short, the same process yields shell-material and food; and we discover that the last link in the series is derived, not from the vegetable world as we have heretofore been taught to believe, but from the inorganic. On the other hand, if this be denied, we have no alternative but to assume that the lower the creature the less need is there for special organs to perform special functions, and that the humble Rhizopod or Polycystine may digest, secrete, excrete, and (for all we can adduce to the contrary) think into the bargain!

Although the discovery, at extreme depths, of creatures devoid of visual organs would simply indicate that life is in no degree dependent on light, or on the previous manifestation of plant-life said to be inseparable from it, it is impossible to regard the occurrence, under similar conditions, of any of the more highly organized forms whose morphological relations involve the possession of organs of vision, without perceiving that upon this single fact hangs the question whether living creatures were originally constituted to live beyond the influence of light, or became gradually habituated to live at extreme depths. For it is manifest that the detection of the most rudimentary eyes would prove that the creatures possessing them had originally lived in shallow water, and that they had slowly accommodated themselves to the new and abnormal conditions by which they were surrounded—the sense of sight failing under the absence of the natural stimulus, and the organs of sight either degenerating or becoming obliterated from disuse, during a succession of generations.

The caves of Carniola, Adelsberg, Kentucky, and other localities furnish us with numerous examples of blindness in animals living beyond the influence of light, and enable us to trace the transition, from the simple loss of nervous sensibility to the partial or entire occultation of the external organs of sight, which is observable as the animals recede from the outer world and take up their abodes where the darkness is more or less complete. But inasmuch as blindness involves the presence, however rudimentary or degenerate, of a special set of organs, we should not be warranted in regarding creatures as originally created to pass their lives in the gloomy depths of these caves, or in any other position beyond reach of light, unless all trace of rudimentary visual organs was absent, and there was distinct evidence that the types to which such creatures belonged occurred elsewhere with those organs developed.

The identity of the *Ophiocomæ* obtained from an extreme depth in the North Atlantic with the *Ophiocoma granulata* of shallow water, although affording presumptive evidence that their ancestors, like their contemporaries met with on our own coasts, were not specially created to live in that position, is by no means a proof of the fact. The Ophiuridæ do not possess the so-called "eye-spots" of the Asteriadæ and Solasteriæ; and even if they did, the proof of these spots being true organs of vision supplied with nervous ganglia is far too feeble to be generally accepted. But, fortunately for the fate of the question, the *Ophiocomæ* referred to are not the most highly organized creatures that have been discovered at great depths, inasmuch as a "Crustacean of bright colours" is reported to have been brought up from 1400 fathoms, by Mr. Torell the director of the recent Swedish Expedition to Spitzbergen*. In the absence of a detailed description of this Crustacean, it would be premature to speculate on the indications afforded by its visual organs. But since the Crustaceans possess these organs without any exception†, the fact is of the highest value, as affording additional proof that creatures originally constituted to live in shallow water may gradually become acclimatized and live under the extraordinary conditions prevalent at extreme depths in the ocean.

With regard to the effect of light on the production of colour in animals, and,

* No official report of this expedition having appeared up to the present time, my information is derived from a letter which appeared in the 'Athenæum' of Dec. 7, 1861, which bears the stamp of perfect authenticity.

† See 'Anatomy of Invertebrata,' Siebold, English edition, vol. i. p. 325.

conversely, the absence of colour said by Forbes and nearly all other writers to ensue from diminution of light, I have only one series of facts to advance; but these appear conclusively to prove that, although intensity of light may, as averred, engender intensity of tint, the absence of light does not involve its loss or even its deterioration. The star-fishes obtained from a depth of 1260 fathoms were as brilliantly coloured as if they had lived their lives in the temperate zone and the shallowest waters; whilst, singularly enough, individuals of the same species dredged up from 100 to 200 fathoms in the fiords of West Greenland were of a dusky hue. *Acmæa testudinalis*, *Natica Grœnlandica*, *Chiton marmoreus*, *Hippolyte polaris*, *Boltenia picta*, *Ophiocoma bellis*, *Cottus glacialis*, and *Nullipora purpurea* were of the ordinary vivid tints. *Solaster papposa* and *Ophiura texturata* were alone slightly blanched; but this effect cannot be attributable to absence or diminution of light, since the same species occurred in shallow water, on the Labrador coast, with no greater development of colour. Lastly, as above stated, the Crustacean brought up by Mr. Torell from 1400 fathoms is described as "of bright colours." With these facts before us, and keeping in recollection the evidence that has been adduced to show that the creatures heretofore discovered at extreme depths are descendants of species that once flourished in shallow water, it appears reasonable to conclude that colour is a hereditary character, and that, inasmuch as a creature originally colourless cannot be made to assume a brighter exterior by subjection to a brighter sun, so neither can the natural colour of a creature be destroyed by removal to the opposite conditions. Deterioration of colour may, and undoubtedly often does occur, as in the case of animals removed from tropical to temperate regions; but the cases are not sufficiently numerous to be regarded otherwise than as exceptional. And when they do occur I cannot help thinking that we should search for the cause, not in the diminution of light, but in the impaired vital functions sure to attend removal from normal to abnormal conditions. Sickly animals, as well as sickly plants, lose their natural colour in tropical countries. In this case diminution of light can have nothing to do with the result. The more highly tinted fishes of our own latitudes degenerate in colour when out of season. And, lastly, there are examples of the reverse action being produced —that is to say, loss of colour by removal of animals or plants from their natural habitats in temperate regions to tropical ones. On these grounds I

venture to believe that the colours on the feathers of a bird, the wing of a butterfly, or the shelly covering of an Echinoderm are as purely hereditary as their various organs, and that, in artificially produced varieties, we must regard the condition as to light as only holding equal rank with numerous other secondary conditions, which produce their effects through the vital functions *.

Having thus described the various agencies on which the bathymetrical distribution of marine life depends, together with their modes of operation and relations to each other, it remains for me to prove (what I have heretofore been obliged to take for granted, in order to avoid endless repetition) that the star-fishes and other creatures, referred to as having been obtained from great depths, were captured in a living condition in the midst of their natural haunts.

When we take into consideration the more obvious changes which attend the removal of a living creature from the deep-sea bed to the surface, we can hardly fail to perceive that the chances are vastly against the detection of a remnant of vitality. For, although, as I have endeavoured to show, the increase of pressure which prevails at the bottom of the ocean exercises no more injurious effect on creatures formed to live under it than the pressure at the sea-level does on terrestrial animals, and there is every reason to believe that marine creatures in general, and the lower tribes in particular, can undergo very considerable alterations of it with impunity, the case becomes totally different when a creature is suddenly removed from a depth at which the pressure is estimated by tons on the square inch, to one at which it dwindles into a few pounds.

All animal tissues whatever are said to be originally formed of minute cells which are impervious to gases or fluids save through endosmotic action. But, since no free gaseous matter can exist permanently at extreme depths, the contents of such cells must be fluid and of the same, or nearly the same, specific gravity as the surrounding medium. This is a material character, inasmuch as it enables

* This view derives a singular degree of confirmation from the following facts, for which I am indebted to Mr. P. L. Sclater, the able Superintendent of the Zoological Society's Gardens. The brilliant plumage of the Scarlet Ibis (*Ibis rubra*), a native of Tropical America, and the equally brilliant scarlet of portions of the plumage of the Pine Bullfinch (*Pyrrhula enucleator*) and the Crossbills (*Loxia*), both natives of the northern parts of Europe, fade in an equally marked manner on their removal to this country; so that we have here presented to us deterioration of *the same colour*, in the one instance on removal of a bird from a tropical to a temperate climate, in the other on removal from a boreal to a temperate climate.

us to understand why the ocean never yields up its dead, and why, if tenanted by living things as we now know it to be, dead creatures never rise up to the surface to disclose the mystery of their past being. Decomposition may go on, but not putrescence. The molecular constitution of the particles of animal matter may be altered, and eventually, perhaps, their elements may enter into new chemical combinations; but, since no gaseous matter could be retained in a gaseous form within the cells or larger cavities of dead organisms, and the unfailing result of endosmotic action would be to place in absolute equilibrium with the surrounding medium every portion of the structure, no decrease of specific gravity can occur to cause it to ascend from its position. The same conditions would apply to living things originally formed to inhabit extreme depths, or acclimatized through a vast succession of generations; for although minute differences of specific gravity may exist between the fluid contained within their cavities and the medium in which they reside, there is no ground for supposing such differences to be greater than exist between the bodies of creatures constituted to live in shallow water and the medium in which they sustain themselves. If this view be correct, it explains how it is that the submarine fauna remains as immutably chained to the sea-bed under all circumstances as the terrestrial fauna remains chained to the surface of the earth. Here and there we detect the fossil ized forms of oceanic creatures, some of which, in all probability, were denizens of deep water; but under one set of conditions alone does the detection become possible—namely, after the lapse of countless ages, during which sea and land have exchanged dominions.

Again, we should bear in mind that the oceanic Rhizopods, although perhaps more tolerant of change, in virtue of extreme simplicity of structure, than any other tribe of creatures with which we are acquainted, are, for the same reason, the least calculated to exhibit active vitality under sudden change. Under the most favourable circumstances, and only after the lapse of considerable time, do the shallow-water forms when in captivity exhibit pseudo-cyclosis or extend their pseudopodia. And hence, since it is in the last degree unlikely that those brought up from extreme depths should present these evidences of vitality, we must rest content with collateral proofs. Fortunately these are of a very satisfactory kind.

The minute calcareous shells of the Foraminifera are the most frequent and widely distributed organisms of the ocean. They occur in all seas in more or

less abundance. But there is one genus (namely, *Globigerina*) which may be regarded as essentially oceanic, since it is to be found in all latitudes, and at all depths ranging from 50 to 3000 fathoms. Its seat of maximum development is on the deeper areas of the sea-bed. There, like the sands of the shore, it strews hundreds of square miles of surface, and apparently builds up vast strata. The great superficial current of the Atlantic does not bear it away in countless multitudes from tropical coast-lines, nor does the body of the ocean itself constitute its habitation*. Nevertheless it is evident that there is an intimate association between the Globigerina-deposits and the Gulf Stream; for wherever we trace the one sweeping across the surface of the ocean, we are almost sure to detect the other resting on the sea-bed; and where we fail to trace the one, we almost as surely fail to detect the other. Thus, between the Faröe Islands and Iceland, between Iceland and East Greenland, and for a considerable portion of the direct route between Cape Farewell and Rockall, *Globigerina* is the prevailing form in the deposits; whereas between Greenland and Labrador, along the belt traversed by the Arctic current, and in a southerly direction along the coast of Labrador, it is either absent or occurs only in such very limited quantity as to prove that the conditions are favourable to its increase in the one case, and unfavourable in the other†.

It is obvious that if the deposits were due to the subsidence of organic matter transported by currents, instead of being formed of well-marked groups of species, or (as is sometimes the case) almost exclusively of a single species, they would *invariably* consist of heterogeneous assemblages of minute organisms derived partly from coast-lines, and partly from the oceanic regions previously traversed

* By sinking very fine gauze nets to considerable depths, I have repeatedly satisfied myself that *Globigerina* does not occur in the superficial strata of the ocean. On one occasion, a small bag was drawn up through 700 fathoms of water, in a locality where *Globigerina* abounded on the sea-bed, without entrapping a single shell.

† I have only had one opportunity of noting the characters of the recent Foraminiferous deposits of the southern hemisphere, namely, on the Agulhas bank to the southward of the Cape of Good Hope. There, in 100 fathoms water, I found *Globigerina* forming a nearly pure deposit (about 75 per cent.), the area of which was marked by a definite boundary-line, depending probably on the current which sets round the Cape from the eastward. This deposit differed in no respect from the deposits of the North Atlantic, except in the less massive character of the shells. Hence it would appear that massiveness increases with depth, or, as is more probable, that it is a consequence of it.

by such currents. Lastly, inasmuch as the shells of *Globigerina* surpass in massiveness and density those of any of the other minute structures met with in the deep-sea deposits, excepting the Polycystina—if we assume the deposits to be formed by the gradual subsidence of organic atoms from the transporting currents, it follows that the proportion of light forms to heavy ones would invariably be the greatest at the greatest distances from land,—a result which is not in accordance with observation.

The extreme lightness of some Foraminiferous deposits has been alluded to by Captain Maury, in his admirable work on the 'Physical Geography of the Sea,' as "suggesting the idea that the sea, like the snow-cloud with its flakes in a calm, is always letting fall upon its bed showers of these microscopic shells;" and he adds, "the ocean, especially within and near the tropics, swarms with life; the remains of its myriads of moving things are conveyed by currents, and scattered and lodged in the course of time all over its bottom: this process, continuing for ages, has covered the depths as with a mantle, consisting of organisms as delicate as the macled frost, and as light as the undrifted snow-flake on the mountain" *.

This flocculent character is distinctly observable on the immediate surface-layer of all deposits, and in a few cases, in which the quantity of extremely fine amorphous particles is excessive, it extends to some depth. Such is the condition observable in those localities where the Foraminifera are either absent or constitute the smallest percentage of the material. But in the majority of the deposits, the flocculence does not extend beyond half an inch or an inch below the surface, and it is then replaced by a stratum of the utmost tenacity. This marks the limit of the amorphous non-mineral particles, and the point at which the consolidation of the heavier atoms commences. Although satisfied of the correctness of that portion of Captain Maury's statement which describes "the *remains* of myriads of moving things as being conveyed by currents, and scattered and lodged in the course of time all over" the sea-bottom, I am unable to confirm by my own experience either in the North or South Atlantic that portion of it which relates to "showers of microscopic" (Foraminiferous) "shells." Free-floating Foraminifera are undoubtedly to be met with on the surface of the ocean, as well as free-floating Polycystina, Diatomaceæ, and other less known and

* 'Physical Geography of the Sea,' by Captain Maury. London, 1858: p. 265.

common organisms; but these never constitute the bulk of the deep-sea deposits, as *Globigerina* does. They live within reach of the surface, and are more frequently to be seen in tropical regions; but there is good ground for the belief that the amount of minute animal and vegetable life in tropical and extra-tropical latitudes is far more evenly balanced than has generally been supposed, and that the preponderance to which Captain Maury and other observers have drawn attention as characteristic of the tropics is dependent, not so much on the superabundance of forms within the tropics, as on the rarity of those favourable atmospheric conditions upon which the presence at the immediate surface of extra-tropical forms depends *.

Some of the Globigerina-deposits are of great purity; but I have reason to believe I originally overestimated the percentage of shells and débris, and that the singular absence of amorphous particles in the two specimens on which my estimate was based was due to percolation of water through the mass of the material during its progress from the bottom to the surface. The average proportion of shells varies from 70 to 85 per cent., the remainder consisting of amorphous particles and variable quantities of mineral matter, Polycystina, Diatomaceæ, Sponge-spicules, and not unfrequently fragments of Echinoderm structure.

Turning from the shell, which, in this as in the other Foraminifera, furnishes no characters distinctive of vitality, and, in the majority of the species, does not even enable us to pronounce whether they are recent or fossil, we find that there is nothing either in the quantity, the colour, the consistence, or the optical appearances of the soft parts to indicate that the *Globigerinæ* of the pure deposits do not live where they are discovered. From the difference in colour between the surface-layer of the deposits and the mass beneath, and also owing to the extreme tenacity of the inferior stratum, it appears probable that the living *Globigerinæ* are altogether confined to the former,—this view receiving additional support from the fact that the aspect of specimens taken from the surface corresponds with that of shells known to be alive, whereas the dingy look of those from the subjacent stratum corresponds with that of shells known to be dead. In one case the colour is a vivid but light burnt sienna, the fleshy matter viscid

* The observations of Dr. Joseph Hooker in the Antarctic Sea tend rather to prove a superabundance of the minute organic forms in its waters.

and inclined to coalesce again when crushed, and the retracted pseudopodia are occasionally seen forming minute bosses on the external surface of the shell; in the other, the colour is a dusky brown inclining to grey, the fleshy matter is not viscid, and there are no traces of the pseudopodia. Lastly, the definite boundaries of the Globigerina-deposits, to which allusion has already been made, afford presumptive evidence that the increase of the organisms is dependent on conditions prevalent on the spot, and consequently evidence of vitality.

The association of the more extensive Globigerina-deposits with the Gulf Stream and its several offshoots in the North Atlantic is dependent, I conceive, on the vast supplies of carbonate of lime brought down to it by the great rivers that discharge themselves into the Gulf of Mexico and the Caribbean Sea. Captain Maury combats the idea that the "Mississippi is the Father of the Gulf Stream," and quotes Captain Livingstone as having "overturned this hypothesis by showing that the volume of water which the Mississippi empties into the Gulf of Mexico is not equal to the three-thousandth part of that which escapes from it through the Gulf Stream." He also points out that the water of the Mississippi is fresh, whilst that of the Gulf Stream is salt; and that the waters of the Mexican Gulf and Caribbean Sea are salter than the waters of like temperature in those parts of the ocean through which the Gulf Stream flows, the phenomena being accounted for by the excessive evaporation which takes place in the waters poured into the Gulf Stream and Caribbean Sea by the great equatorial current*.

However true Captain Maury's view may be with regard to the other saline constituents of sea-water, I venture to think it cannot be so in the case of the carbonate of lime, or, indeed, the calcareous salts generally. These we know are essentially derived from fresh-water discharges. The surface waters of the ocean are those which contain the smallest quantity of calcareous matter. The great equatorial current is quite superficial, and on the African side it only receives the outpourings of two rivers, namely, the Niger and Senegal, which, though large, are much inferior in size and extent to the Amazon, Orinoco, Magdalena, Rio Grande, and Mississippi—one and all of which debouch into the equatorial current either before or after it sweeps into the Caribbean Sea and Gulf of Mexico, and pour forth into the waters destined to emerge again as the Gulf Stream the vast stores of calcareous matter they bring down from the interior of

* 'The Physical Geography of the Sea,' p. 26 *et seq.*

the American continents. The massiveness of the shells, in the greater portion of the Foraminiferous deposits obtained on the bed of the North Atlantic, clearly shows that the material of which they are composed is present in its waters in abundance. If the views suggested by me regarding the increase of carbonate of lime with the depth be correct, or even supposing the superabundant supply indicated by the presence of the calcareous deposits to be due to the uninterrupted supply of carbonate, irrespectively of its increase with the depth, the phenomena here indicated serve to corroborate them, and we have presented to us an example of disintegration of strata on the one hand, and reconstruction on the other, on the grandest scale that the earth affords.

The facts connected with the discovery of highly organized radiate animals at extreme depths may justly be regarded as establishing a new era in marine zoology; for, if we attentively examine their bearings, we shall find that, whilst they throw a flood of light on the conditions essential to the maintenance of life in existing seas, they serve at the same time to explain anomalies in the history of some of the older fossiliferous strata, and thus add another link to the chain that binds the Present with the Past.

In order to render apparent the full significance of the Star-fish sounding, I shall endeavour briefly to detail the geographical relations of the locality in which it was taken; the mode in which it was effected; the proofs that the creatures were captured at the bottom; and, lastly, the reasons for believing that, although originally a shallow-water species, these Star-fishes had gradually, and through a long series of generations, accommodated themselves to the abnormal conditions incident on the subsidence of the sea-bed.

The sounding was taken in lat. 59° 27′ N., long. 26° 41′ W., about halfway between Cape Farewell and the north-west coast of Ireland,—the distances being, from the nearest part of Greenland 500 miles, of Iceland (namely, the "Blinde Skier" rock) 250 miles, and the Rockall Shoal about 400 miles.

It is a very notable fact that the position thus indicated is within 100 miles to the north-eastward of that assigned to the "Sunken land of Buss" in old charts*; and that, at a spot about 100 miles to the westward, where the previous sounding was taken, a decrease of depth was indicated amounting to 512 fathoms. For, since it is in the last degree improbable that the shallowest

* See Diary, pp. 63, 64, and 65.

locality in this latitude should have been thus accidentally struck, and it is but reasonable to conclude that the spot laid down in the old charts as a "Sunken land" should still be the shallowest, there is good ground for supposing that the depth continues gradually to decrease from the westward locality, where it is 748 fathoms, to the reputed position of the Sunken land. The probability is enhanced, moreover, from the circumstance of its being only twelve miles to the eastward of the meridian laid down in the French map by M. Fleurieu as that of "Buss." Lastly, we find that if a line passing through the axis of volcanic action in Iceland (that is to say, extending from its north-easterly to its south-westerly extremity) were produced in the latter of these two directions, it would as nearly as possible cross the position of the Star-fish sounding and the "Sunk land" so often referred to. Now we know that subterranean forces have been in active operation in the direction of Iceland at a very recent period, and that a submergence has taken place of certain volcanic islands which were suddenly heaved up from the sea-bed. Apart from other evidence, this fact is obviously of less value than it would have been had the submergence of the islands taken place gradually; but, viewed in conjunction with the subsidence known to have been taking place for several centuries along the southern shores of Greenland, and in the absence of sufficient reason for repudiating the testimony of the early Scandinavian, Venetian, and French hydrographers, it leaves very little room for doubt that a vast area of the sea-bed, involving the whole of these positions, has shared in the submergence.

In all soundings demanding accuracy, it has been customary to determine the depth by one operation, and to secure the specimen of bottom by another. On the present occasion, the depth (1260 fathoms) having been ascertained, a new form of "deep-sea dredge"* was lowered; but, in consequence of its partial failure, a second apparatus (namely, the conical cup) was employed, 50 fathoms of line in excess of the recorded depth being paid out in order to ensure the unchecked descent and impact of the instrument at the bottom. The "dredge"

* The "deep-sea dredge" is really, what the name implies, a dredging- and not a sounding-machine. It was devised by the Chief Engineer of the 'Bulldog,' Mr. Roughton. Although somewhat imperfect, owing to the necessity for carrying out the design with such materials as were available at sea, it might readily be made a most efficient instrument. For natural-history purposes it is obvious that a dredging instrument would always be preferable to one which merely closes on such portion of the surface as it happens to come in contact with.

had already brought up a small quantity of unusually pure Globigerina-deposit and some small stones. The second instrument came up quite full of the deposit; but it was neither so free from amorphous matter, nor did it contain any of the small stones. Adhering, however, to the last 50 fathoms of line, which had rested on the ground for several moments, were thirteen *Ophiocomæ*, varying in diameter across the arms from two to five inches. None of these relaxed their grasp on emerging from their natural element, but continued, for a considerable period after detachment from the sounding-line, to move about their spine-covered arms, thus clearly proving that, although their continued adherence may have depended in some degree on clonic spasm caused by the diminution of pressure, or on the entanglement of their spines in the fibres of the hempen line, their vitality was at all events far from extinct.

Here then we have the accuracy of the first operation conclusively established by the two succeeding ones; the nature of the bottom brought up by the dredge verified by that procured in the conical cup; the proof that fifty fathoms and no more rested on the ground supplied in the correspondence of the three soundings; and, so far as the sounding apparatus is concerned, proof that the Star-fishes had no opportunity of attaching themselves to any portion of the line except that which rested on the bottom. If we examine the remaining evidences, we shall find that it is impossible to arrive at any other conclusion than that the Star-fishes were captured on the sea-bed itself, and not at any point intermediate between it and the surface.

Commencing with the habits of the hard-shelled Echinoderms, there is ample evidence of their being essentially ground-living animals—that is to say, unfitted both in virtue of their structure and specific gravity to raise themselves to any distance, or for any lengthened period, from the bottom. Edward Forbes states that "they are almost all free animals, creeping about at the bottom of the sea;" and adds that their coriaceous skin, which is commonly strengthened by calcareous plates or spines, "distinguishes them from the Medusæ, free-swimming animals of the most delicate and membranous texture"*. In Professor Owen's recent work on Palæontology, the characters of the Echinoderms are given as follows:—"Marine, commonly free repent animals, with the integument in most perforated by erectile tubular tentacles, hardened

* 'British Star-fishes,' by Edward Forbes. London, 1841: Introduction, p. 12.

by a reticulate deposit of calcareous salts, and in many armed with spines" *. Professor Rymer Jones describes the Ophiuridæ as having "the rays long and simple" (in contradistinction to *Comatula* and *Gorgonocephalus*), and says "they resemble the tails of so many serpents, but nevertheless are possessed of moveable lateral spines on each side of every ray, which, although but mere rudiments of what are seen in *Comatula*, may still assist in locomotion, or perhaps contribute to retain the prey more firmly when seized by the arms,—the rays themselves being composed of many pieces curiously imbricated and joined together by ligaments; so that they are, from their length and tenuity, extremely flexible in all directions, and serve not only for legs adapted to crawl on the ground, but are occasionally serviceable as fins, able to support the animal in the water for a short distance by a kind of undulatory movement" †.

Lastly, in the 'System der Asteroiden,' by Müller and Troschel, "the section of the Ophiuridæ which want the pedicellariæ and the anus is divided into two subdivisions, Ophiuræ and Euryalæ," and it is most distinctly stated that the former "have arms fitted only for walking" ‡.

These statements suffice to show that the structural peculiarities of the Ophiuridæ are such as altogether to incapacitate them for raising themselves for any distance, or lengthened period, from the bottom. Assuming, however, the possibility of their having been carried from shallow water by a current, in order to account for their adherence to such a limited portion of the sounding-line as 50 fathoms out of 1310, it is also necessary to assume that they swept past in a closely compacted column, precisely at the period when these fifty fathoms passed downwards or upwards—a contingency far from probable even if the line had been stationary, but rendered in the last degree improbable when it is borne in mind that it was moving through the water at a mean speed of at least sixty yards per minute.

Again, it is hardly possible to believe that creatures constituted to inhabit coast-lines, and dependent on the bed of the sea for their food, could have retained vitality during the time occupied in drifting the 250 miles between the

* 'Palæontology,' by Richard Owen. London, 1860: p. 29.

† 'Animal Kingdom,' by Rymer Jones, F.Z.S. London, 1841: p. 140.

‡ See 'Reports on the Progress of Zoology and Botany,' by Professor C. Th. v. Siebold. Published for the Ray Society. London, 1841-42: p. 331.

spot at which they were captured and the nearest land. The only superficial current known to exist in this region *, instead of flowing from Iceland or any of the northern coasts, flows towards them, and could not have transported these Star-fishes from any position nearer than the eastern edge of the Newfoundland banks. Of the presence of a deep-seated current there is no certain proof. I have alluded in my Diary † to the indications of a drift between the Faröe Islands and Iceland as being requisite to account for the slow transport of the volcanic particles distributed in defined belts along that region, and have stated my reasons for regarding it as a deep branch of the descending Spitzbergen current which flows under the ascending branch of the Gulf Stream in its transit to the equator. It is well known that a cold drift moves from the North and South Polar regions towards the equator in order to equalize the temperature and keep up the balance of the saline ingredients of the ocean. But in latitudes beyond the influence of melting ice this drift must necessarily flow at such depth as to involve the presence of the very conditions hitherto regarded as fatal to animal existence, and at a speed which would be insufficient to support, and far less to transport, creatures of such size and weight as those referred to. Lastly, whether the Star-fishes are supposed to have drifted to the position in which they were captured by a superficial or a deep-seated current, or to have propelled themselves from some distant coast-line, it appears to me that their vitality and healthy condition under such circumstances can only be regarded as increasing, instead of diminishing, the difficulties in the way of an explanation of the phenomena.

But, fortunately, the evidence on which I maintain that these *Ophiocomæ* were captured on the sea-bed itself, in the midst of their normal haunts, is not altogether of a presumptive kind; nor is the discovery of animal life at extreme depths restricted to two examples amongst the Ophiuridæ and Foraminifera.

Immediately on the completion of the sounding under notice, I carefully examined the digestive cavity of one of the *Ophiocomæ*. The contents consisted of a number of fresh-looking *Globigerinæ* more or less broken up, minute

* I am indebted to Sir Leopold McClintock for the following observations, which clearly attest the transit of the Gulf Stream in the locality at which the Star-fish sounding was taken:—Temperature of air 44° F.; temperature of the surface of the sea 48° F.; temperature of sea at 100 fathoms 48½° F.

† See Chapter I., p. 5 *et seq.*

yellow amorphous particles, a few bright-yellow oil-globules, and several ova. In two specimens examined at a subsequent date, I found the *Globigerinæ*, amorphous particles, and oil-globules as before, but no ova; whilst in the deposit itself were detected two small Echinoderm-spines which, on comparison, proved to be identical with those on the arms of the *Ophiocomæ*.

In three soundings (including that in which the Star-fishes were obtained) taken in the under-mentioned positions and depths—namely, lat. 59° 27′ N., long. 26° 41′ W., depth 1260 fathoms; lat. 58° 23′ N., long. 48° 50′ W., depth 1913 fathoms; and lat. 56° 43′ N., long. 11° 55′ W., depth 1268 fathoms—minute cylindrical tubes occurred, varying from $\frac{1}{8}$th to $\frac{1}{3}$ an inch in length, and from $\frac{1}{50}$th to $\frac{1}{20}$th of an inch in diameter. These were built up almost exclusively of very small Globigerina-shells and still more minute calcareous débris cemented together. Two or three such tubes were found by me in each of these soundings, but I failed to extract the animals from them in a sufficiently perfect condition to admit of identification. I am nevertheless able to state positively that the tubes contained some species of Annelid, and think it highly probable that certain borings to be seen on Foraminiferous shells in the same deposits may have been effected by it. But, whether this be the case or not, it is quite clear that an Annelid lives at the depths indicated, and *there* builds up its tenement. The shells forming the outer layer of the tubes were colourless and freed of all sarcodic matter; but the internal surface of the tubular cylinder was lined with a delicate yet distinct layer of reddish chitine.

It has been stated that these tubes are *almost* exclusively built up of Globigerina-shells. The proportion is probably about 98 per cent., the remaining 2 per cent. being made up of Sponge-spicules, Diatom-valves, and minute particles of other mineral matter.

In a sounding taken in somewhat shallower water, namely, in 871 fathoms, in lat. 61° 35′ N., long. 24° 9′ W. (about halfway between Cape Rekianess and the position of the Star-fish sounding), I detected two tubes, probably formed by the same or a closely allied species of Annelid, but differing from the last in the total absence of Globigerina-shells, and their replacement by nearly equal proportions of minute calcareous débris and Sponge-spicules. The size of the tubes in this sounding would appear to be modified by the more compact "stowage" of which their material is capable; and hence the diameter is

reduced in the two specimens to $\frac{1}{85}$th and $\frac{1}{80}$th of an inch respectively,—about 2 per cent., again, consisting of what may be regarded as accidental particles, namely, fragments of Foraminiferous shells and Diatom-valves.

The importance of these facts can scarcely be overrated; for, although the presence of Annelid-tubes neither proves the vitality of their occupants nor of the Foraminifera and Sponges which supplied the material to construct them, yet, since we know that all tubicolous Annelids are essentially ground-inhabiting creatures, it is manifest that the tubes must have been built upon the sea-bed, and hence that the living Annelids must have been there present to build them. And further, if we admit the connexion between the bored Foraminiferous shells met with in the same deposits and these Annelids, we must also admit the probability that the latter found within the bored shells suitable living nutriment to recompense them for their trouble.

But the material of the tubes supplies its share of valuable evidence likewise; for we find that whereas in the 1260- and 1268-fathom deposits, which consist chiefly of Foraminiferous shells, the tubes are formed almost exclusively of this material, in the 871-fathom deposit, which consists of a nearly equal admixture of calcareous and siliceous matter, the tubes partake of the same proportions, clearly showing that, both in the kind and quantity of material employed, the Annelid is dependent on the character of the deposit on which it lives.

In a sounding taken in lat. 63° 31′ N., long. 13° 45′ W., in 682 fathoms, a portion of a Serpula-tube, $\frac{5}{12}$ths of an inch in length, and about $\frac{3}{16}$ths of an inch in diameter, belonging to a known species, came up in such a condition as to leave no room for doubt that it had been broken off the rock or stone to which it was adherent by the sounding-machine, and that the animal was living; whilst a smaller *Serpula* and a cluster of apparently living Polyzoa were adherent to its external surface. A minute living *Spirorbis* also occurred in this sounding. Lastly, from a depth of 445 fathoms, within a short distance of the south coast of Iceland, a couple of living Amphipod Crustaceans were obtained, and a filamentous Annelid about three-quarters of an inch in length.

Bearing in mind, then, 1st, that the *Globigerinæ* have never been detected free-floating in any number in deep, or forming deposits in shallow water; that a considerable proportion of those met with in the deep-sea deposits exhibit every appearance of vitality; that their maximum development is associated with

the presence of the Gulf Stream, but only through the operation of collateral conditions prevailing at great depths below the current itself; and that fresh-looking specimens were present in the digestive cavities of *Ophiocomæ* brought up from a depth of 1260 fathoms;

2ndly. That the *Ophiocomæ* arrived at the surface in a living and vigorous condition, adherent to that portion only of the sounding-line which had rested on the bottom; that the number captured affords presumptive proof of the gregarious habit of the order having remained unaffected by change of conditions; that the detection of ova and *Globigerinæ* within their cavities indicated a perfectly normal state of their reproductive and nutritive functions; that no superficial or deep current capable of drifting them in a northerly or north-easterly direction from any coast-line nearer than Newfoundland exists in this part of the ocean, and, if it did, that it would not account for the most important phenomena;

3rdly. That in certain deposits Annelid-tubes were found, the nature of which proves them to have been constructed on the sea-bed, of material there accumulated;

4thly. That a living *Serpula*, *Spirorbis*, and group of Polyzoa were brought up, in a distant locality, from a depth of 680 fathoms;

5thly and lastly. Taking into consideration the arguments adduced to prove that the conditions which prevail on the deep-sea bed are not incompatible with the maintenance of animal life, and the extreme improbability that the creatures heretofore discovered at great depths are merely exceptional or accidental examples; it will, I think, be conceded that the presence of a living fauna in the deeper abysses of the ocean has been fully established.

Assuming, then, that the creatures referred to were captured in the midst of their normal haunts, the inquiry naturally suggests itself, Whence did they originate? and are we to regard the localities in which they were found as their genetic centres, or only as isolated colonies tenanted by species whose genetic centres are to be looked for elsewhere? These questions can only be answered by a further appeal to concomitant facts.

"Every living race of plants and animals," writes Professor Phillips, "exists in a province of space over which by natural conditions it has been diffused, within which by natural conditions it has been restrained, and beyond which it only passes by a change in these conditions. Thus one place of origin is indi-

cated for each species of plant and animal—one locality where it first appeared, whether it still remain there confined to a limited region, or have wandered far away without losing its prominent characters through length of time, change of conditions, mixture with other races, or any of the innumerable incidents of the 'struggle for existence'" *.

Bearing in mind the law thus comprehensively set forth, and connecting it with the extraordinary fact that the *Ophiocomæ*, the *Serpula*, and the *Spirorbis* of the deep-soundings one and all belong to well-known littoral species†, we are irresistibly led to the inference that their acclimatization must have kept pace, during a vast sequence of generations, with the changes going on in the portion of the sea-bed inhabited by them, and, hence, that, under sufficiently favourable circumstances, species may accommodate themselves to conditions differing so widely from those under which they were originally created, that their subjection to them under circumstances less favourable inevitably results in their extinction.

I have endeavoured to establish that an extensive area of sea-bed to the southward of Iceland has undergone subsidence, partly on the evidence afforded by the depths, and partly by that supplied from old charts and tradition. The subjoined striking passage from Forbes's admirable memoir "On the Existing Fauna and Flora of the British Isles" will serve to show that, on geological grounds alone, he arrived at a similar opinion:—"Great as the changes appear to be affecting the distribution of land and water during recent geological periods, as compared with the present, assumed by me in this essay, I cannot but express my conviction that future research will not only confirm these, but prove that still greater took place during the epochs under inquiry. The phenomena of the glacial formations, the peculiarities in the distribution of the animals of that epoch, and the relations of the existing fauna and flora of Greenland, Iceland, and Northern Europe are such as strongly to impress on my mind that the close of the Glacial epoch was marked by the gradual submergence of some great northern land, along the coasts of which the littoral Mollusks, aided by favouring currents, migrated; whilst a common flora became diffused over its hills and plains. Although I have made icebergs and ice-floes the chief agents in the transportation of an Arctic flora southwards, I cannot but think that so complete a transportation

* 'Life on the Earth,' by Professor Phillips. London, 1860: p. 24.

† The species are *Ophiocoma granulata*, *Serpula vitrea*, and *Spirorbis nautiloides*.

of an Arctic flora as we find on the Scottish mountains was aided, perhaps mainly by land to the north now submerged. It is difficult otherwise, too, to account for the cessation of the Arctic littoral Mollusks in the Scottish glacial beds, and their replacement by other forms on the English and Irish beds of the same epoch. When dredging on the great fishing-banks bounding the Zetland Isles and forming long ridges now 50 and more fathoms below the sea, stretching from some unexplored point in the north, like long arms, down to the Scottish shores, and covered with angular fragments of the rocks of which they are formed, I was strongly struck with their resemblance to the rugged and broken surfaces of the neighbouring islands, and could not divest myself of the notion that these banks were submerged mountain-chains. Before, however, this can be fairly assumed, we must have a re-examination of the vegetable and animal productions of Iceland, that great centre of volcanic power, the presence of which where it is, is possibly connected intimately with the phenomena we have been endeavouring to interpret" *.

The outline thus shadowed forth of that ancient barrier which is supposed to have stretched across from East Greenland (probably, however, at some point far to the northward) towards the shores of Northern Europe derives a singular degree of confirmation from the soundings. For, on reference to the map, it will be seen that a vast area of sea-bed to the southward of Iceland, extending to the 30th degree of west longitude on the one hand, and to the Faröe Islands and Hebrides on the other, gradually diminishes in depth as it advances northwards, in all probability constituting the boundary of an archipelago rather than a continuous continent, across which the various species of animals and plants made their way southwards. When that archipelago existed, the Hebrides and Faröe Islands were probably united, whilst Rockall formed a large but distinct island, and another still larger island rose up out of the sea between the 57th and 60th degrees of latitude, and about the 30th degree of west longitude. On the northern flank of this island the Star-fish sounding was taken. Lastly, the Faröes and Iceland were then separated only by a narrow channel, situated about the 15th

* 'Memoirs of the Geological Survey of Great Britain,' vol. i. p. 398.

I cannot refrain from here paying my humble tribute of admiration and respect to a lamented friend and college-mate. The first time I ever saw a dredge put down was in the Firth of Forth, in company with Edward Forbes, nine and twenty years ago.

degree of longitude, whilst the Westmann Islands and the Blinde Skier respectively formed portions of the southern and south-western coast-line of Iceland.

Viewed by itself, the subsidence of this large tract, although of interest as yielding a glimpse of the facies of the ancient Atlantic, and even suggestive of the acclimatization of the creatures now distributed over its bed, could hardly have been regarded in a higher light than as offering a plausible explanation of a most unlooked-for phenomenon. But it assumes a far more important bearing when coupled with the fact that these creatures belong to existing shallow-water species, and that they exhibit no appreciable trace of variation, notwithstanding the change of conditions to which they have been subject for a vast series of generations. In short, no proof of subsidence could be more complete, no proof of the truth of the doctrine of single specific centres more convincing, than the detection under such circumstances of a colony of acclimatized Star-fishes, belonging to a species typical of the Boreal province, well known to range from the confines of the arctic circle to our own shores, and already shown to have accommodated themselves to a depth of 200 fathoms without variation; whilst the fact of subsidence being general throughout the whole area is rendered probable by the discovery of sessile Annelids, also belonging to known shallow-water species, at a depth of 680 fathoms, halfway between Iceland and the Faröe Islands.

The occurrence of a shallow-water *Serpula* at such a depth is important, moreover, from the evidence it yields of the subsidence having been extremely gradual, and not merely the result of local and temporary submarine volcanic action; for, whilst creatures having powers of locomotion might have evaded the consequences of sudden subsidence by migration to shallow water, the sessile Annelids must inevitably have been destroyed. If these facts are correct, the detection of shallow-water species on isolated submerged areas of sea-bed may yet enable us to determine whether such areas have been nearer the surface at some anterior period, and may thus afford us a glance, otherwise unattainable, at the lost landmarks of a bygone geological epoch.

It will perhaps be asked how it is that the *Ophiocomæ*, if descendants of a littoral species, exhibit no definite divergence of character from individuals of the same species which have never been removed from normal conditions. To this it may be answered that certain orders of animals are known to be much

more prone to variation dependent on changes in the conditions by which they are surrounded than others, whether we regard the variation observable in the same individual or the same species at different periods of its history*. And, further, if the views offered by me are correct, it is evident that such changes of conditions must operate more frequently and powerfully at the surface than at great depths. Now, since *Ophiocoma granulata* is found on the British and Scandinavian coasts at depths varying from 10 to 50 fathoms, whilst in Greenland, as already stated, it is met with at 200 fathoms, it is reasonable to suppose that, if prone to variation, it would exhibit clear traces of it at the greater of these depths. Such is not the case, however; and hence the persistence of type at the still more profound depth of 1260 fathoms becomes intelligible, although nevertheless surprising.

It has already been stated that *Orphiocoma granulata* ranges at the present day from the confines of the arctic circle to our own shores. I failed to detect it in the immediate neighbourhood of Rekiavik, but this was probably in consequence of the peculiar scoriaceous nature of the bottom along the south-western portion of the island. In the absence of data for determining whence the species became diffused across such a wide longitudinal range, it would be useless to speculate whether the isolated deep-sea area on which it has now been found formed its genetic centre; whether the transport or migration of individuals towards that area took place prior to its isolation and complete submergence; or whether it was colonized after isolation. From what has been stated regarding the inability of the Ophiuridæ in their mature state to rise to any distance or for any lengthened period from the bottom, it is apparent that transport of individuals could only be effected by a powerful current. During the larval condition, however, of certain species of Ophiuridæ, they sometimes float at the surface of the sea, and, hence, under favourable circumstances, might be drifted towards isolated areas fitted to receive them. In the Foraminiferous deposit of the Agulhas bank, I dredged up larval Ophiuridæ, from a depth of 100 fathoms, measuring not more than a quarter of an inch across the arms, whilst specimens obtained from the immediate surface over the same deposit were of still more minute dimensions. These had, in all probability, drifted from the adjacent

* According to Edward Forbes, no important variation has taken place in the Ophiuridæ since the extinction of the species found fossil.

coast-line, and were destined to subside to the bottom as soon as their calcareous structure became sufficiently consolidated to counterbalance the buoyancy of the soft parts*. In the case of the *Ophiocomæ* of the sounding, the presence of ova distinctly proves that the generative function was being carried on even at that great depth; and consequently the undetermined state of the question regarding the genetic centre of the species is of very secondary importance; for, whether the submerged area was colonized by emigrants from adjoining coasts, prior to its isolation, or by larval *Ophiocomæ* which had subsided upon it after it had become partially or completely submerged, the phenomenon of subsequent acclimatization (which is the one more particularly under consideration) remains entirely unaffected.

Another very singular fact in connexion with the Star-fish sounding demands notice, namely, its proximity to the circle of uniform temperature†. It will be recollected that the sounding was taken in lat. 59° 27′ N., whereas the mean latitude of the homothermal circle, according to Sir James C. Ross's observations in the southern hemisphere, is 56° 25′‡. The position corresponding most closely, in the Southern Sea, with that of the Star-fish sounding is in lat. 58° 36′ S., long. 104° 40′ W.—a position at which it is stated to be "about a degree higher than in other parts of the ocean, and also rather further to the southward." In this situation the temperature of the air is stated to have been 32° F., of the surface 41°, and at 100 fathoms 40°·8§; whereas, in the locality of the sounding,

* In 1850, Mr. T. H. Stewart detected a larval *Ophiocoma* in abundance on a parasitic sponge brought up from a depth of 53 fathoms in the British Channel. The same larval form was also met with in pools left by the receding tide,—the fact of its being found both in shallow and deep water being regarded as proof that the mature animal spawns in both situations. (Annals and Magazine of Natural History, 2nd ser. vol. xviii. p. 387.)

† It is worthy of note that on the Agulhas bank, to the southward of the Cape of Good Hope, where fish are abundant, the bottom consists of calcareous deposit, and that to the northward of Rockall (where an extensive fishery has recently been re-discovered) the bottom is essentially of a similar character, Echinoderm-débris being so plentiful in both localities as to render it probable that the Echinoderms form the food of the fish. Should shallow water still exist in the vicinity of the reputed "Sunk land of Buss," it is possible that a more inexhaustible fish-bank than any yet known may be there met with. It is also remarkable that Loch Fyne, the Dogger Bank and Silver Pits, the Rockall Shoal, and the Labrador and Newfoundland fisheries are all either on, or near, the circle of uniform temperature—a coincidence in position which can hardly be regarded as accidental.

‡ See diagram at p. 99.

§ The mean latitude of the homothermal zone as computed by Sir James C. Ross, in the southern hemisphere, is here given. (See 'Voyage to the Southern Seas,' vol. ii. pp. 227 and 375.)

the temperature of the air was 44°, of the surface 48°, and at 100 fathoms 48½°,—clearly indicating the effect of the Gulf Stream both on the air and water.

It would be futile to speculate on the probable influence which such a region of uniform temperature from surface to bottom may have had upon the bathymetrical distribution of animals, since the nature of the conditions under which acclimatization commences presupposes a period so remote that the sea-bed must have been elevated almost to the surface: but it is not unreasonable to suppose that, as subsidence took place, the increasing uniformity in the temperature and density of the water may have facilitated their acclimatization, and eventually favoured their distribution over the bed of the homothermal sea.

It only remains for me to mention that I have met with no example of any of the Algæ proper below 200 fathoms, and that the only recognizable vegetable structures which occur amongst the deep-sea deposits belong to the lowest order with which we are acquainted, namely, the Diatomaceæ. As already mentioned, however, the appearance presented by the frustules of these, when obtained at depths beyond 500 fathoms, indicates a molecular constitution of the protoplasmic matter differing so materially from that observable in similar organisms taken in a living condition in shallow water as to render it certain that all vegetable life ceases at a limit far short of that to which animal life has now been shown to extend.

Basing my arguments, then, on two facts which I venture to hope are unequivocally proved in the preceding pages, namely, that highly organized creatures have been captured in a living condition at depths vastly exceeding those to which animal life had previously been supposed to extend, and that their presence, where captured, cannot be regarded as an accidental or exceptional phenomenon, it has been my endeavour to establish the following important propositions:—

I. The conditions prevailing at great depths, although differing materially from those which prevail near the surface of the ocean, are not incompatible with the maintenance of animal life.

II. Assuming the doctrine of single specific centres to be correct, the occurrence of the same species in shallow water and at great depths proves that it must have undergone the transition from one set of conditions to the other with impunity.

III. There is nothing in the nature of the conditions prevailing at great depths,

to render it impossible that creatures originally, or through acclimatization, adapted to live under them should become capable of living in shallow water, provided the transition be sufficiently gradual; and hence it is possible that species now inhabiting shallow water may, at some anterior period, have been inhabitants of great depths.

IV. On the one hand, the conditions prevailing near the surface of the ocean render it possible for organisms to subside after death to the greatest depths, provided every portion of their structure is freely pervious to fluid: on the other hand, the conditions prevailing at great depths render it impossible for organisms still constituted to live under them to rise to the surface, or for the remains of these organisms after death to make their appearance in shallow water.

V. The discovery of even a single species living normally at great depths warrants the inference that the deep sea has its own special fauna, and that it has always had it in ages past; and hence that many fossiliferous strata, heretofore regarded as having been deposited in comparatively shallow water, have been deposited at great depths.

PART III.

CHAPTER I.

GENERAL OBSERVATIONS ON THE DEEP-SEA RHIZOPODAL FAUNA.

BEFORE proceeding to describe the minute structures which constitute the principal organic element in the North Atlantic soundings and are distributed more or less abundantly throughout all the deep-sea deposits of the globe, it is necessary to adduce my reasons for having embodied in the present work a general classification of the lowest orders of the animal kingdom which might, with greater propriety perhaps, have formed the subject of a separate memoir.

In preparing for publication the materials at my command I had the choice of two alternatives—that is, either to arrange them according to some artificial system solely with a view to the future identification of particular forms, or, turning aside from the easy but profitless task of species-manufacture, to apply myself to the more legitimate purpose of increasing our knowledge regarding the morphological and physiological characters of the class of creatures to which, with a few rare exceptions, the various organisms belong.

The elaborate researches of Carpenter, Messrs. Parker and Jones, Williamson, Schultze, MM. Claparède and Lachmann, Carter, and others, had already placed in an entirely new light the nature and relations of the *Gromida*, *Foraminifera*, *Actinophryna*, and *Amœbina*; whilst those of Johannes Müller * had put us in possession of much valuable information respecting the *Polycystina* and some allied but still more imperfectly known families of Rhizopods. The *Foraminifera*, with the single exception of the genus *Globigerina*, were neither largely represented in

* 'Über die Thalassicollen Polycystinen und Acanthometren des Mittelmeeres,' von Johannes Müller. Berlin, 1848.

the soundings, nor did they exhibit any very novel or striking characteristics. The study of this family, moreover, was undergoing such a thorough revision by the distinguished physiologist whose name stands at the head of the above list, that any attempt on my part to have forestalled his labours would simply have been presumptuous*. The *Polycystina*, on the other hand, were both more abundantly represented than the *Foraminifera*, and exhibited such an endless variety of form as fully to confirm the opinion at which I had long previously arrived—partly on an examination of living specimens procured in the surface-waters of the tropical seas, and partly from the study of the fossil Polycystine earths,—namely, that in no class of organisms is the tendency to variation more unlimited, or the law of development less understood. To Professor Müller's views regarding the proper basis for a classification of the *Polycystina*, *Acanthometrina*, and *Thalassicollidæ*, it was impossible for me to subscribe, inasmuch as I differed from him not only in the value to be placed on mere differences in form and the mode of repetition of the siliceous portions of these structures, but in the interpretation of those more important characters upon which the ordinal separation of the whole of the Rhizopodal families has, in great measure, been made to depend.

Under these circumstances, and in the firm conviction that the mere description and delineation of a number of objects, with no higher aim than that of augmenting the already perplexing lists of doubtful species, would serve no useful purpose, I resolved to attempt a revision of the classification of the Rhizopods, and to import into it as much of the information obtained, both from the soundings and from other sources, as might be necessary for the due completion of my object.

In a valuable paper by Professor Carpenter, 'On the Systematic Arrangement of the Rhizopoda," which appeared in the Natural History Review for October 1861†,

* In the 'Introduction to the Study of the Foraminifera' (page 56), Dr. Carpenter declares that "The impracticability of applying the ordinary method of definition to the *genera* of *Foraminifera*, becomes an absolute impossibility with regard to species."

† It is necessary to state that the following pages were written subsequently to the appearance of Dr. Carpenter's paper in the 'Natural History Review,' and that his admirable 'Introduction to the Study of the Foraminifera' appeared whilst they were passing through the press. As Professor Carpenter's detailed work in nowise contravenes the views expressed in the preliminary paper referred to, I have only felt called upon to modify a few unimportant passages.

the characters of the three orders into which he proposes to distribute the various families are concisely stated as follows:—

"I. RETICULARIA. The body composed of homogeneous granular protoplasm, without any distinction into ectosarc and endosarc; neither nucleus nor contractile vesicle; pseudopodia composed of the same substance as the body, extending and multiplying themselves by minute ramification, and inosculating completely wherever they come into contact; a continual circulation of granular particles throughout the viscid substance of the body and its extensions. This Order consists of the *Foraminifera* and the *Gromida*.

"II. RADIOLARIA. Incipient differentiation of the protoplasmic substance into ectosarc and endosarc, the former semifluid and granular, the latter more tenacious and pellucid; a nucleus and contractile vesicle; pseudopodia rod-like, usually tapering from base to point, composed of the same substance as the ectosarc, exhibiting little disposition either to ramify or to coalesce, having a more or less regular radiating arrangement, and not showing any constant circulation of granules in their substance, although a movement of particles adherent to their exterior is often to be distinguished. The type of this Order is *Actinophrys*, constituting, with its immediate allies, the family *Actinophryna*; but the Order also includes the *Acanthometrina*, *Polycystina*, and *Thalassicollina*, by the last of which this group is connected with the Sponges.

"III. LOBOSA. More complete differentiation of the protoplasmic substance into endosarc and ectosarc, the former being a slightly viscous granular liquid, and the latter approaching the tenacity of a membrane; a nucleus and contractile vesicle; pseudopodia few and large, being in reality lobose extensions of the body which neither ramify nor coalesce, having well-defined margins, and not exhibiting any movement of granules on their surface, the circulation in their interior being entirely dependent on the changes of form which the body undergoes as a whole. This Order is composed of but a single family, the *Amœbina*, and it is the one which presents the nearest approximation to the Classes *Infusoria* and *Gregarinida*."

It will be seen that whilst these definitions are almost wholly based on the degree of "differentiation" exhibited by the general mass of the sarcodic substance, the names of the Orders point exclusively to the characters of the pseudopodia. For, whether we regard the degree of consolidation of the

superficial protoplasmic layer of the organism—the capability or otherwise of the pseudopodial processes to maintain a separate individuality so long as they remain projected beyond the main mass of the body—the apparent character of the minute granular circulation, either as occurring within the general cavity of the organism or extending *into* the pseudopodia—or the presence or absence of a nucleus and contractile vesicle,—we perceive that the whole of these characters have a mutual dependence one on the other, and are exponents of the gradual advance from that simplest phase of animal being in which the structure is distinguishable from an inanimate jelly only by the cyclosis of granules and the projection of pseudopodia, to the highest phase of Rhizopodal development, in which the characters merge into those of the *Spongidæ* on the one hand and the ciliated *Infusoria* on the other.

Being fully convinced that the principle of classification so admirably propounded by Dr. Carpenter is the only one on which a natural distribution of the Rhizopodal Orders can be established, it is with great diffidence that I now venture to offer such a modification of his arrangement as I conceive to be demanded, not by a conflict of opinion regarding the value of certain characters, but the presence or absence of those characters in some of the families said to exhibit them. At the same time it is a satisfaction to feel that my views diverge from his, for the most part, only in those cases in which his judgment has been based on the descriptions of other observers, and not on personal examination of the living structures.

The principal source of confusion has arisen, I conceive, from Professor Müller's statements with reference to the nature and characters of the pseudopodial processes in the *Polycystina* and *Acanthometrina*—statements which clearly tend to indicate a similarity, if not an identity, in the pseudopodia of these two families, although I cannot admit that they warrant the conclusion that any dissimilarity existed, in Professor Müller's opinion, between those of the *Polycystina* and *Foraminifera*. In drawing attention to the additions to our previous knowledge of the Rhizopods, supplied in Professor Müller's treatise 'Über die Thalassicollen, Polycystinen und Acanthometren des Mittelmeeres,' Dr. Carpenter speaks of the author as having failed to appreciate the essential relationship between the *Acanthometrina* and *Actinophryna*, "an *Acanthometra* being nothing else than an *Actinophrys* furnished with a siliceous skeleton." As described by

Müller, it would certainly seem to be nothing else; but I hope to be able to prove as I proceed, not only that the *Acanthometrina* do not possess radiate pseudopodia analogous to those of *Actinophrys*, but that *Acanthometra* is as far removed beyond *Actinophrys*, in the degree of development attained by the ectosarc*, as *Actinophrys* is beyond *Pamphagus* or *Lieberkuhnia*, whilst the *Polycystina*, which are ranged with the *Acanthometrina* in Professor Müller's system, do not exhibit any advance in the degree of differentiation of the protoplasmic substance beyond that observable amongst the *Foraminifera*. Hence it would appear that the separation of *Actinophrys* and *Amœba*, in Dr. Carpenter's system, is due rather to an assumed but unreal affinity between *Actinophrys*, *Acanthometra*, and the *Polycystina* than to any valid distinction between the characters of the two first-named genera; for it must be admitted that the disinclination of the pseudopodia to coalesce, and the presence of a nucleus and contractile vesicle (the last of which organs is never to be met with in the *Polycystina*, the *Acanthometrina*, or the *Thalassicollidæ*) are characters of far higher significance than the apparent absence of granular circulation in *Actinophrys*, which is seen in *Amœba*, and the mere difference in size, shape, and persistence of each pseudopodial extension. I say, *apparent* absence of granular circulation, because it is difficult to conceive that in two organisms varying but little, if at all, in the average consolidation of their ectosarc, and both possessing a nucleus and contractile vesicle (the last of which organs Dr. Carpenter† considers as "superseding the necessity of the general protoplasmic circulation"), such a difference should exist—or, if it exists, that it should be deemed of distinctive value.

Had the close analogy between *Actinophrys* and *Acanthometra* really subsisted, it is hardly possible that Professor Müller could have failed to detect it notwithstanding the fact that his reliance on the characters furnished by the hard parts would naturally have led him to regard these two families as distinct. But he leaves no room for doubt as to his views concerning the pseudopodia of the Rhizopods under notice; for he distinctly states that, having had an opportunity

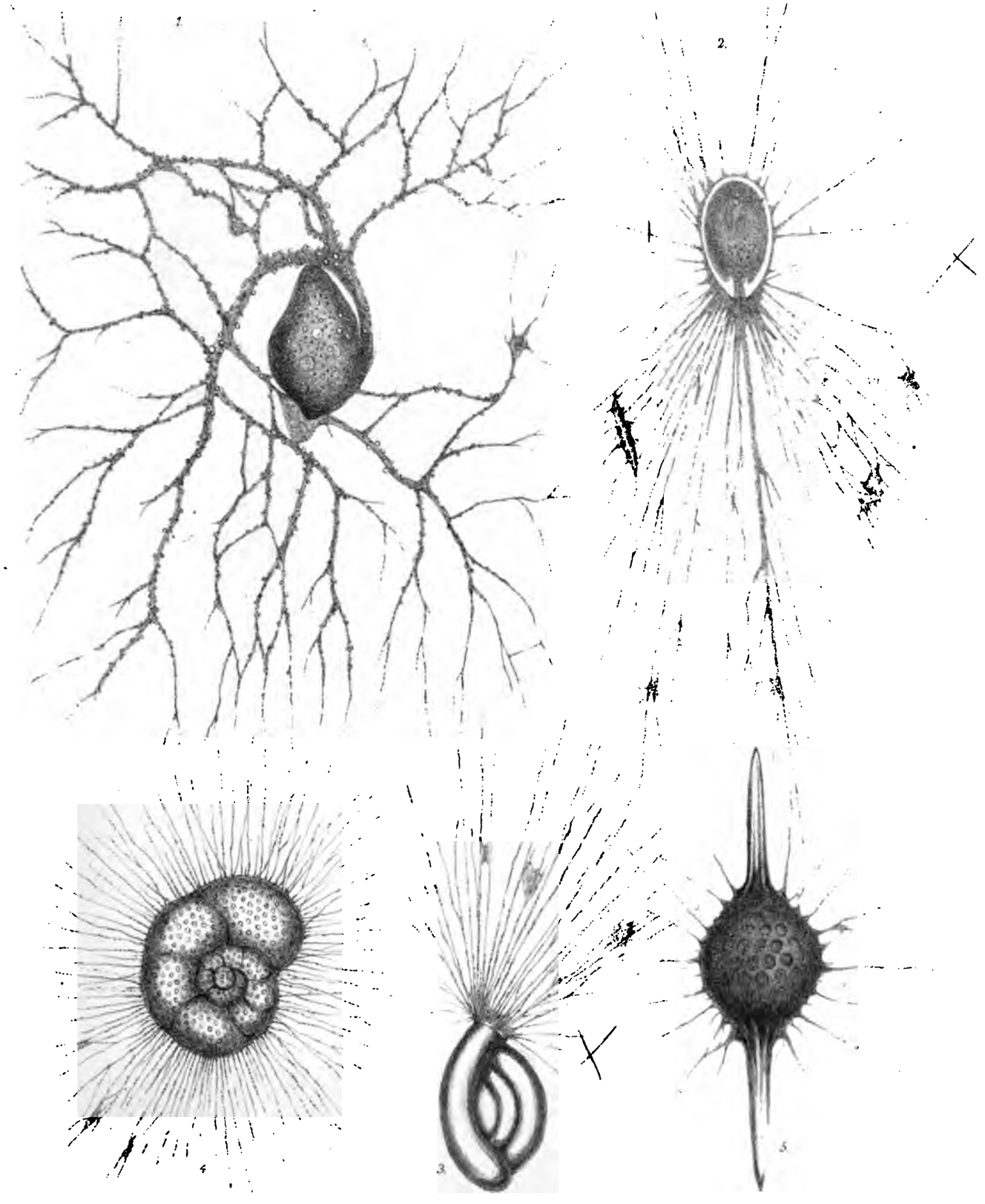
* The very appropriate terms *ectosarc* and *endosarc* were originally applied by Dr. T. Strethill Wright to the external condensed layer and the internal viscid mass of the sarcode of the Rhizopods.

† "On the Systematic Arrangement of the Rhizopoda," by William Carpenter, M.D., F.R.S., 'Natural History Review,' No. 4, Oct. 1861, p. 462.

Allich, del et lith. M & N Hanhart. Imp.t

OPHIOCOMA, ADHERING TO THE SOUNDING LINE, IN THE POSITION IN WHICH IT REACHED THE SURFACE FROM A DEPTH OF 1260 FATHOMS.

John Van Voorst, Paternoster Row, 1862.



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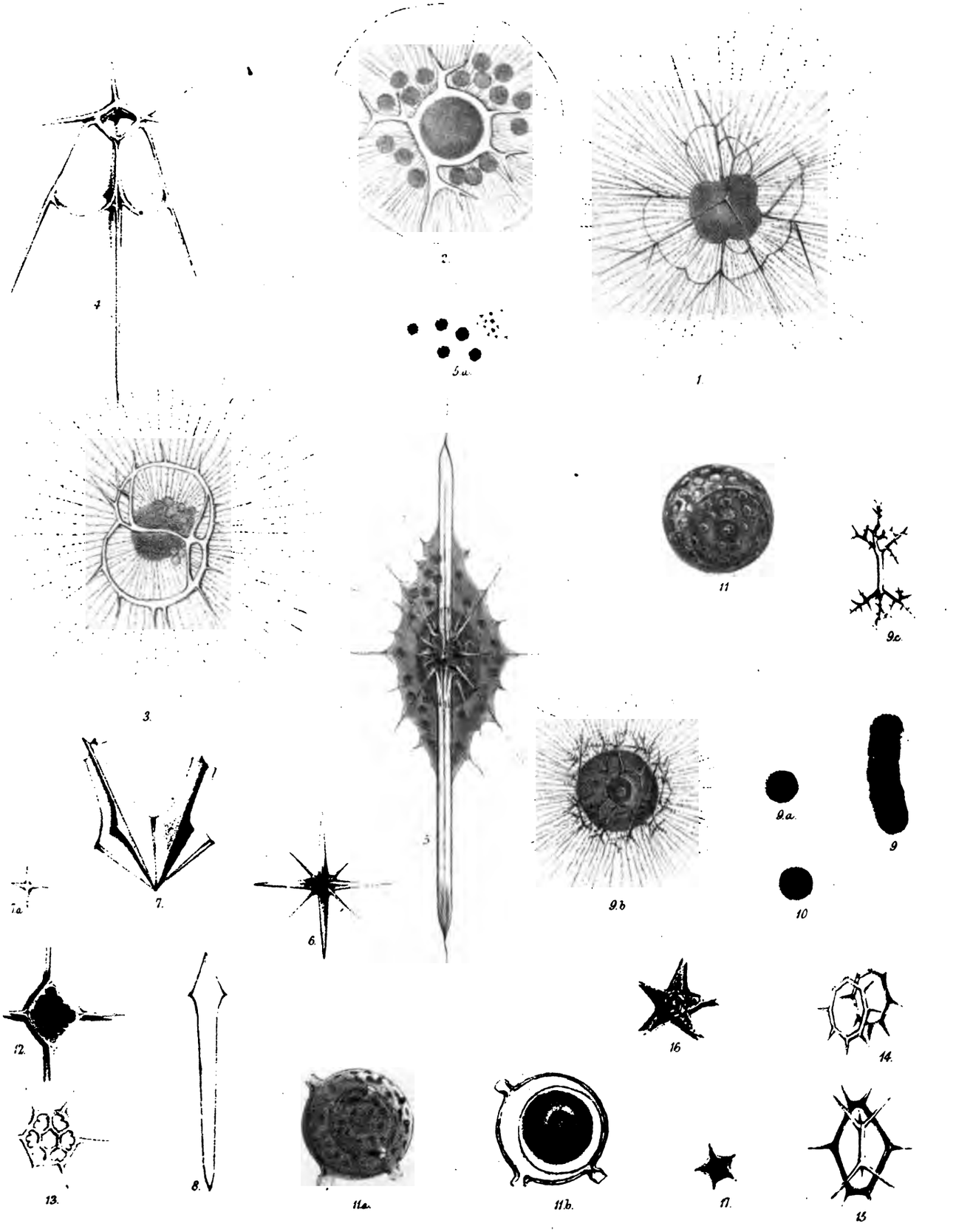
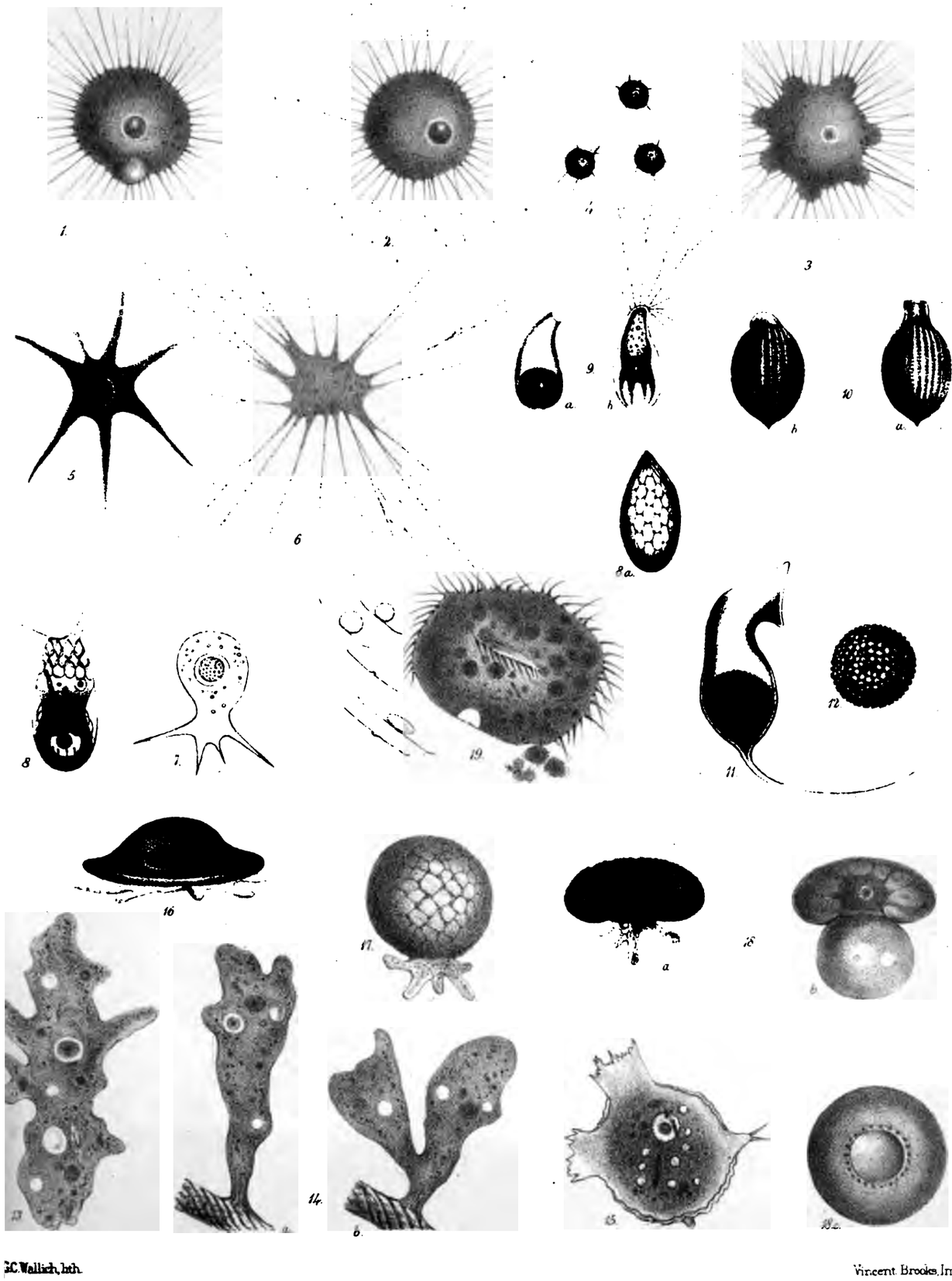
LIEBERKUHNIA. GROMIA DISCORBINA. MILIOLA. HALIOMMA.

Vincent Brooks

John Van Voorst, Paternoster Row, 1862.



PLAGIOCANTHA. LITHOCIRCUS. ACANTHOMETRA.
THALASSICOLLA. DICTYOCHA. ACTINISCUS.



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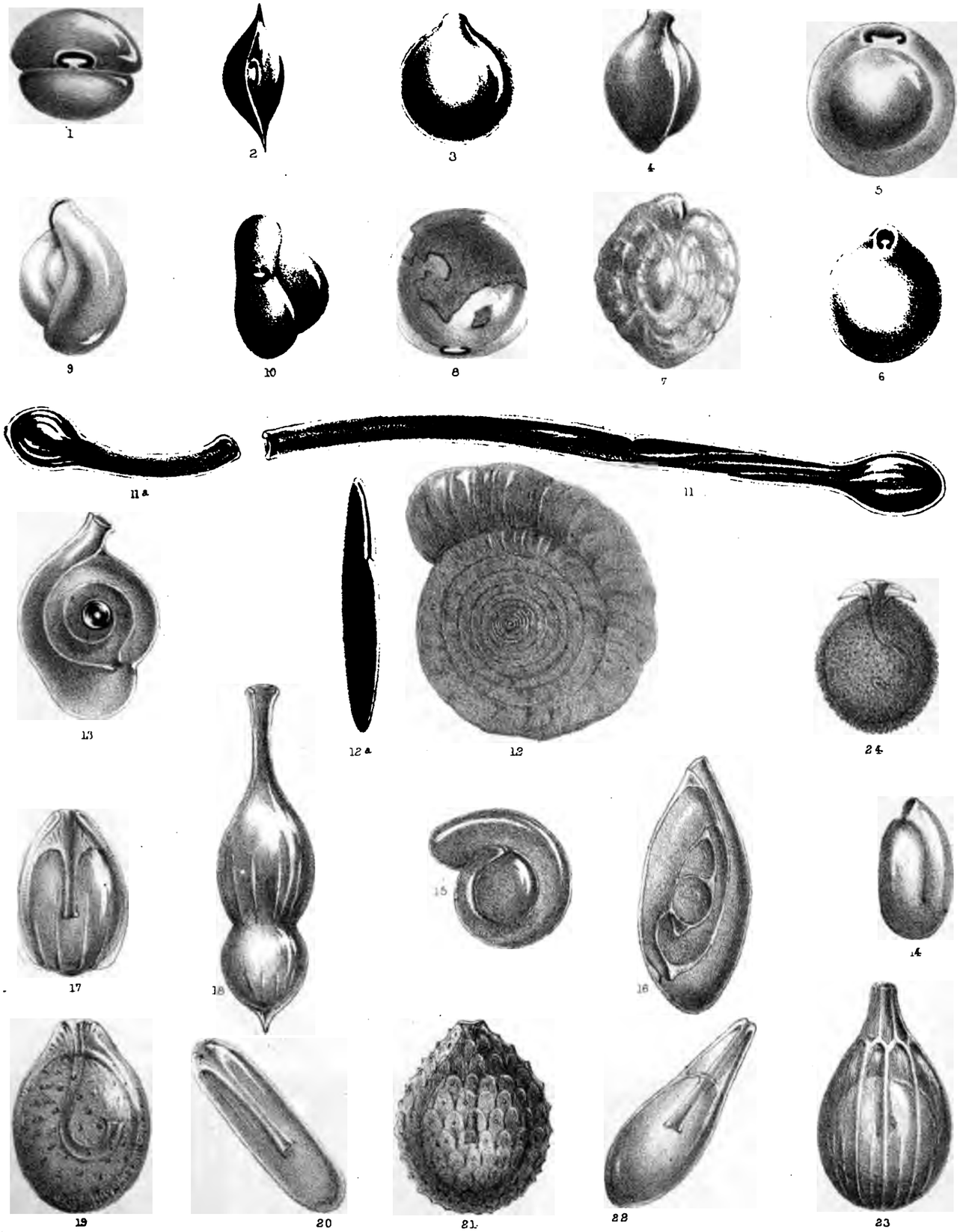
ACTINOPHRYS. LAGYNIS EUGLYPHA. CADIUM. PROTOCYSTIS.
ACANTHOSPHŒRA. AMŒBA. DIFFLUGIA ARCELLA.
(KERONA)

John Van Voorst, Paternoster Row, 1862.

Plate. 5.



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BILOCULINA. QUINQUELOCULINA. SPIROLOCULINA.
CORNUSPIRA. LAGENA.

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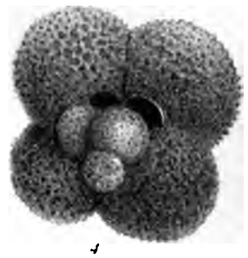

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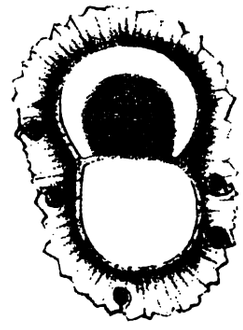

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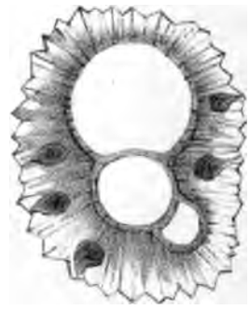

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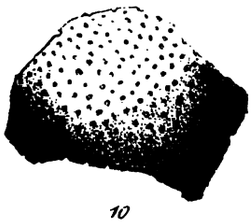

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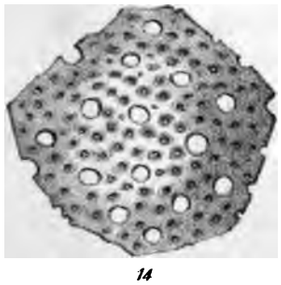

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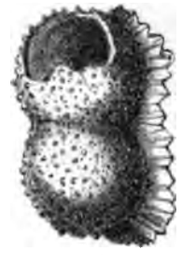

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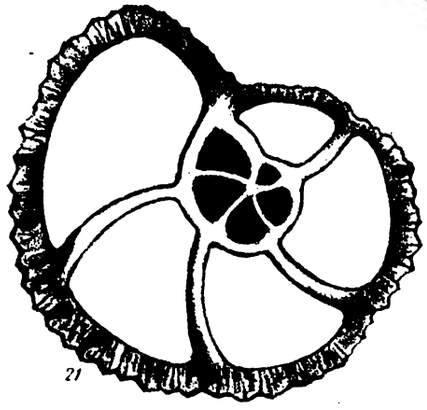

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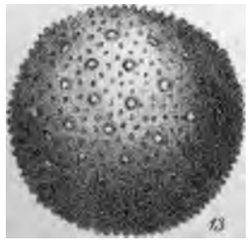

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Vincent Brooks, Imp

GLOBIGERINA ORBULINA DISCORBINA . LITUOLA . ROTALIA .

John Van Voorst, Paternoster Row. 1862.

1.

With the Author's Compliments.

ON THE

PHYSIOLOGICAL ACTION OF THE CALABAR BEAN

(PHYSOSTIGMA VENENOSUM, BALF.).

BY

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FROM THE

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MDCCCLXVII.

XLVIII.—*On the Physiological Action of the Calabar Bean* (Physostigma venenosum, *Balf.*). By THOMAS R. FRASER, M.D., Assistant to the Professor of Materia Medica in the University of Edinburgh. Communicated by Professor CHRISTISON, M.D., D.C.L., V.P.R.S.E.

(Read 17th December 1866.)

In 1855, the Professor of Materia Medica in the University of Edinburgh, in a paper read before this Society, directed the attention of physiologists to some of the remarkable properties of the Calabar bean.* In 1862,I presented a graduation thesis to the University of Edinburgh on the "Characters, Actions and Therapeutic Uses of the Ordeal Bean of Calabar." The principal results I had obtained at that time were that this substance causes death by either syncope or asphyxia, the latter being due to an effect on the spinal cord and on the respiratory centres; that the symptoms resemble those of cardiac or pulmonary embarrassment, according to the quantity of the poison administered, and to its rate of absorption; and, also, that the topical application of this agent to the eyeball, or to its neighbourhood, produces a marked and rapid contraction of the pupil and various disturbances of vision.† Since then, and more especially because of the peculiarity of the last of these conclusions, a lively interest has been taken in this substance. Its actions on the eye have been investigated by nearly all the leading ophthalmologists of Europe and of America, and its general physiology has occupied the attention of many distinguished students of biology. Nor have these labours been barren of practical results. Ophthalmic medicine has adopted this agent as one of its important remedies, and there can be little doubt that general medical practice will soon include in its Pharmacopœia a drug of so great energy.‡

The present investigation was undertaken for the purpose of extending and supporting my previous results, with some of which subsequent observers have disagreed; but I purpose to take an opportunity of examining these discrepancies with some detail in a different place. The effects which follow the topical application to the eyeball will be merely alluded to in this paper, as this portion of the subject has not been completed. Enough has, however, been done to convince

* Proceedings of the Royal Society of Edinburgh, vol. iii. p. 280; and Monthly Medical Journal, vol. xx., 1855.

† Edinburgh Medical Journal, 1863, and pamphlet.

‡ Since this sentence was written the *Physostigmatis Faba* has been admitted into the edition of the "British Pharmacopœia," published in 1867.

me of the insufficiency of the views hitherto advanced, and to suggest the advisability of extending my observations.

Preparations.

In 1863, I separated from the kernel, from the spermoderm of the bean, and, also, soon after, from the excrement of a lepidopterous insect which feeds on the kernel,* an amorphous active principle, possessing the general properties of a vegetable alkaloid, for which I proposed the name Eserinia, derived from Eserĕ, the usual name of this ordeal-poison at Calabar; and with it a few experiments were made, some of which have been published. Shortly afterwards, I succeeded in obtaining this alkaloid in, apparently, a state of greater purity, and as a crystalline substance, to which I gave the name Eseria. A crystalline acid, having a similarity to, and being probably identical with, tartaric acid, was also obtained from the kernel at that time. In the present investigation, however, an extract, prepared by acting on the finely pulverised kernel with boiling alcohol (85 per cent.), has been used. This preparation contains a considerable proportion of fatty matter, which prevents its complete solution in water; and, as the division into separate doses of a mere watery suspension would lead to many inaccuracies, it was found necessary to weigh the requisite quantity, separately, for the majority of the experiments. This extract is hygroscopic, which further required that it should be dried and kept in an exsiccator in order to ensure an unvarying preparation.†

Subjects of Experiment and Comparative Effects of Doses.

With few exceptions, the experiments were made with the common frog (*Rana temporaria*), birds, and various mammals. It was found that fatal results were produced with the smallest quantity on birds; and that the largest doses, in proportion to weight, were required by amphibia. A dose of one-sixteenth of a grain proved rapidly fatal to a pigeon weighing nine ounces and three-quarters; whereas a frog, which weighed 726 grains, has recovered from three grains of extract—a quantity sufficient to produce death in a dog of average size.

A. ACTION THROUGH THE BLOOD.

As I have already, in a previous paper, described with considerable detail, the general symptoms which follow the administration of physostigma, it will be unnecessary to give them here. It has also been shown, on the same occasion, that the more rapid the absorption of the poison the more quickly are fatal effects produced, and that the active principle may be absorbed by any living

* On the Moth of the Esere, or Ordeal Bean of Old Calabar. The Annals and Magazine of Natural History, May 1864, pp. 389–393.

† The varying potency of an extract possessing the property of absorbing moisture may unfit it for therapeutic purposes, but the tincture I have already recommended (*op. cit.* sect. iii.) will prove a sufficient substitute, and it has the great advantage of constancy of strength.

tissue. From the following experiment it is proved that prolonged digestion with gastric juice does not impair the energy of Calabar bean:—

Experiment I.

A gastric fistula was formed in a healthy dog, and, some days afterwards, and while the animal was in good health, 500 grains of gastric juice were withdrawn from the stomach. Four hundred grains of this were mixed with half a grain of extract of physostigma, received in a flask with an arrangement to impede evaporation, and placed in a water-oven at a temperature of 98° F. The digestion was continued for twenty-four hours, when the fluid was placed in a capsule and evaporated at 85° F. The resulting extract was finely pulverised, heated with alcohol of 85 per cent., filtered, and again evaporated to dryness. Contact with distilled water removed an acid fluid, which was made alkaline by excess of magnesia, and agitated in a bottle with chloroform. The chloroformic solution was removed by a separating funnel and evaporated, and the resulting brown extract was suspended in distilled water. A drop of this was applied to the conjunctiva over the right eyeball of a rabbit, whose pupil, before the experiment, measured $\frac{1}{8}\frac{3}{0}$ths × $\frac{1}{8}\frac{1}{0}$ths of an inch. In eight minutes, the pupil was $\frac{5}{8}\frac{5}{0}$ths × $\frac{1}{8}\frac{3}{0}$ths; in fifteen minutes, $\frac{5}{8}\frac{6}{0}$ths × $\frac{5}{8}\frac{3}{0}$ths; in twenty minutes, $\frac{4}{8}\frac{4}{0}$ths × $\frac{5}{8}\frac{6}{0}$ths, and it continued in this contracted condition for many hours. The remainder of the fluid was injected under the skin of a young pigeon, and caused its death in eight minutes.

Several small pieces of hard-boiled white of egg were placed in a flask with the remaining 100 grains of gastric juice, and digested under exactly the same conditions, and at the same time, as the extract of physostigma. They were found to be completely dissolved in less than ten hours. There could, therefore, be no doubt as to the activity of the gastric juice which had been employed.

This merely confirms the result before obtained, of fatal effects following the introduction of the poison by the digestive system.

I believe that BRINTON first demonstrated that a poison which had been administered by the blood may be excreted by the stomach and intestines.* This was proved with tartar emetic; and, more recently, TAYLOR has published evidence showing that arsenic also may appear in the stomach although it had not been administered by the alimentary canal.† I took an opportunity of examining if a similar event occurs in poisoning with physostigma.

Experiment II.

Five grains of extract, suspended in water, were injected into the right jugular vein of a dog, and caused the death of the animal in eleven minutes. The stomach was immediately removed, and its contents, along with some of its mucous coat, obtained by scraping, were partially dried at a low temperature, and then boiled with successive portions of spirit (85 per cent.) acidulated with tartaric acid. The tincture was concentrated by distillation, and then evaporated to dryness. The extract was treated with distilled water, filtered, and agitated with ether until the fatty matters were removed. The remaining watery solution was made alkaline by the addition of carbonate of sodium and shaken with ether; and the ethereal solution was distilled. A yellowish, alkaline, amorphous residue was obtained, weighing three-fifths of a grain, and having a disagreeable animal odour. A minute portion of this extract was mixed with two

* Cyclopædia of Anatomy, article "Stomach;" Lancet, 1853, vol. ii. p. 599; and Lectures on the Diseases of the Stomach, 2d edit., 1864, p. 54.

† Guy's Hospital Reports, vol. vi. p. 397.

drops of distilled water and applied to the conjunctiva of a white rabbit, in the presence of my friend, Dr CRUM BROWN. Before the application, both pupils had a diameter of $\frac{1}{8}\frac{3}{0}$ths of an inch, in a full light. At first a little irritation was caused. In thirteen minutes, the pupil had contracted to $\frac{5}{8}\frac{}{0}$ths, and in eighteen minutes to $\frac{3}{8}\frac{}{0}$ths; the other pupil still remaining at its original diameter of $\frac{1}{8}\frac{3}{0}$ths. This extreme contraction continued for upwards of an hour; but in two hours the pupil was $\frac{7}{8}\frac{}{0}$ths, and by the following morning it had resumed its original diameter.

It would, therefore, appear that physostigma, when administered by a vein, finds its way into the stomach—a method of poison-excretion which has been established in the cases of antimony and arsenic.

Although this investigation has for its principal aim the determination of the exact method in which physostigma acts, and the demonstration, as far as possible, of the histological structures which it influences, it may be necessary to describe, at this place, the general symptoms which follow the administration of a poisonous dose. In the case of mammals, I have already entered fully into this subject in a previous paper, from which I extract the following descriptions:*—

"When a *small* fatal dose is administered to one of the lower animals, a train of symptoms is produced usually in the following order:—A slight tremor is first seen, especially at the posterior regions, and this extends forwards to the anterior extremities and the head. The limbs yield immediately afterwards, the posterior becoming generally first paralysed, and the animal lies extended in a state of almost complete muscular flaccidity. A few attempts may be made to recover the normal position, but they are usually ineffectual. The bowels, in most cases, are evacuated, and urine is passed. The pupils generally *contract;* as the symptoms advance, the respiration becomes slow and irregular, with a distinct stertor accompanying both inspiration and expiration, and frothy mucus escapes from the mouth. Muscular twitches occur, and often continue after respiration has ceased. Reflex action cannot be produced by either pinching or pricking the skin. By-and-by the eyelids do not contract when touched or even when the eyeball is pricked. On lifting by the ears, the limbs hang inertly, and the only sign of life is an occasional gasping inspiration, which also soon ceases, and the animal appears dead.

"Consciousness is preserved during the whole time, until the power of expression is lost. During incomplete paralysis, proofs of sensation may be obtained by pinching the ears or pricking the skin. Immediately after death the pupils dilate.

"On opening the body the various muscles which are cut contract. The diaphragm and muscles of the extremities may be excited to action by pinching the phrenic and sciatic nerves, and the contractility of the muscles generally is retained for some time after death. The heart is found acting regularly, and the intestines exhibit distinct vermicular action. The heart may continue its action

* *Op. cit.* sect. ii.

for one hour and a-half after death. Its chambers usually cease to contract in a definite order, the left auricle first losing its spontaneous action, then the right and left ventricles, and, after an interval, the right auricle. The large veins in the thorax are found distended. . . . The lungs are engorged—in two experiments this had proceeded to such an extent that detached portions sank in water. . . .

"When a *large* fatal dose of the kernel is administered, the hind limbs almost immediately yield, and the animal falls. It lies flaccid, and in any position, on the table, and exhibits muscular power only by a few twitches. The pupils contract; in a few cases fluid escapes from the nostrils and mouth, and the lachrymal secretion is increased. Reflex action cannot be produced by irritation, and the respirations, after a few gasps, cease.

"The pupils dilate immediately after death. On opening the body, muscular twitches occur. . . . The heart is found distended and passive; irritation, however, produces contraction for about ten minutes after death. The vermicular action of the intestines is very much diminished, and can scarcely be observed. . . . The mesenteric arteries and veins may be readily distinguished by the colours of their contents."

The following will serve to illustrate the symptoms with frogs:—

Experiment III.

Three grains of extract of physostigma, suspended in twenty minims of distilled water, were injected, by WOOD'S syringe, into the subcutaneous cellular tissue at the back of a light-coloured frog, weighing 430 grains. For four minutes it appeared perfectly unaffected and jumped about normally; after which time some increase occurred in the respiratory irregularity which is always found in frogs. In seven minutes, the respiratory movements of the chest had ceased; but those of the throat continued for other four minutes (eleven after injection). About this time, the movements of the animal were sluggish; the fore legs gradually began to separate until they no longer supported the chest and head; and the posterior extremities were affected in a like manner, and soon after lay extended and flaccid. Weak voluntary movements, however, continued until fifteen minutes after the exhibition of the poison; and, for some time after this, irritation demonstrated the continuance of reflex power. In half an hour, the skin of the frog had undergone a marked change, having become of a dark brown colour. Although now apparently dead, it was not, in a strict physiological sense, really so. Motor nerve-conductivity was retained for many minutes longer; the diastaltic function was not abolished, and, hence, it was possible to show that afferent nerve-conductivity also continued; and the muscular tissue, for many hours, contracted when stimulated, and, in the case of some of the heart chambers, spontaneously and successively did so, for a shorter period.

Into all these, and many other points, it is necessary to enter with detail, and several of them may be overtaken in a somewhat connected manner by examining the cause of what is the most prominent, as well as one of the earliest, of the phenomena described. This is obviously the condition of gradually increasing paralysis.

Action on the Voluntary Muscles.

The peculiar successive tremors, which are observed in warm-blooded animals, at first sight suggest that the paralysis caused by Calabar bean is due to an affection of the muscular system; and the condition of general flaccidity, which so rapidly follows its administration to frogs, appears to favour, as it certainly does not contradict, this opinion. Without pretending that such was the order followed in this investigation, it will, as a matter of convenience, be advisable to examine, in the first place, the effects which are produced on voluntary muscles.

Experiment IV.

A full-grown active rabbit had injected into the subcutaneous tissue of its right flank, three grains of extract, suspended in eleven minims of distilled water. Tremors occurred in two minutes; the anterior extremities soon after yielded; and, in four minutes and thirty seconds, the animal fell, the muscular trembling having increased in vigour and having become general over the body. Respiration ceased in five minutes after the injection, but muscular tremors continued during other three minutes. When the thorax was opened the heart was found dilated and passive. Twenty-four minutes after the administration, galvanic stimulation of the sciatic nerves caused powerful muscular contractions; within thirty-six minutes, these nerves were completely paralysed, though application of the electrodes to any of the voluntary muscles produced marked contractions. These contractions became gradually weaker, but could be distinctly excited until one hour and thirteen minutes after the poison had been exhibited.

The general result in all the other experiments which were performed on warm-blooded animals was the same. Muscular contractility remained after destruction of the function of motor nerves; and this also occurred, in even a more marked manner, with frogs.

Experiment V.—(*Temperature of Laboratory about* 53° *F.*)

By means of Wood's syringe, I injected three grains of extract, in fifteen minims of distilled water, into the lower portion of the abdominal cavity of a frog which weighed 473 grains. The usual phenomena quickly occurred. In sixteen minutes, the sciatic nerve and the neighbouring muscles of the left thigh were exposed and found active.

The muscles were now of a very blue colour, quite distinguishable from their normal appearance; and this colour change was discovered in the serous and fibro-serous tissues also. In about four hours, motor nerve-conductivity was universally destroyed. The heart contracted rhythmically, and at a very reduced rate, until twenty-six hours after the administration, after which, the auricles contracted more frequently than the ventricles, and continued to do so until the heart's action ceased, seventy-three hours after the poison was injected; and, by microscopic examination of the web, it was found that a more or less feeble circulation was all this time maintained. Until this stage, no apparent change occurred in the readiness and vigour with which the striped muscles contracted when directly galvanised; their reaction continued to be alkaline, and they were perfectly flaccid. Soon after the stoppage of the heart's action the blue colour, which has been already mentioned, began to disappear, and in ninety-six hours (four days) the muscles were quite pale. No stiffness was yet observable, and galvanism still induced faint contractions. Rigor mortis commenced soon after this, but its progress was extremely slow, as galvanism produced dimples at the electrodes until 110 hours. When the frog was again examined, at 129 hours after the injection of physostigma, no muscular contraction could be produced by powerful galvanism; rigor mortis was complete; and the reaction of the muscles was found to be acid. Galvanism could produce a very faint contraction of the cardiac muscle,

limited to the points of stimulation, until about the time up to which feeble indications of retained contractility could be obtained in the voluntary muscles.

Experiment VI.—(*Temperature of Laboratory between* 52° *and* 54° *F.*)

To a frog, weighing 379 grains, four grains of extract were administered in the same way as in the preceding experiment. Motor nerve-conductivity ceased in two hours and sixteen minutes, by which time the exposed muscles were found to have become blue. The cardiac action continued rhythmical, though much reduced in frequency, until twenty-seven hours and fifteen minutes, after which, the auricles alone contracted spontaneously till forty-four hours, and then, spontaneous cardiac action entirely ceased. During all this time, the muscles were flaccid, contracted vigorously on the application of weak galvanism, and had an alkaline reaction and a blue colour. Soon afterwards, they became paler and slightly stiff, but it was not until seventy hours after the administration of the poison that galvanic stimulation failed to produce any contraction; and then rigor mortis, with an acid reaction of the muscles, set in.

These three experiments distinctly prove the absence of any paralysing effect by physostigma acting through the blood on striped muscle.

Rigor mortis is delayed for an unusual period after apparent death in cold-blooded animals, and its appearance, in mammals and birds, is certainly not hastened. In both classes this change in the condition of muscles is only indirectly affected by this substance, and that through its influence on the cardiac contractions. When the blood supply of the muscles is stopped their function is suspended, and rigidity follows; but the resulting rigor does not seem to be due, in any other than this indirect method, to the action of physostigma.

This may be more clearly demonstrated by detailing one of many experiments in which a portion of the frog was protected from the influence of the poison.

Experiment VII.—(*Temperature of Laboratory between* 52° *and* 54° *F.*)

The right iliac artery was exposed, by removing a portion of the sacrum, and tied in a frog, weighing 878 grains. Two minutes afterwards, three grains of extract, suspended in ten minims of distilled water, were injected into the subcutaneous cellular tissue at the right shoulder. In a few minutes, a condition of general paralysis existed, and shortly afterwards the skin of the tied limb was much paler than that elsewhere, this contrast becoming more marked as the experiment advanced. In an hour and twenty minutes, the sciatic nerves being exposed, it was found that the left was completely paralysed; while galvanism, applied to the right nerve, or that of the limb protected from the action of physostigma, produced active muscular contractions. The muscles of the tied limb were pale as contrasted with those to which the poison had access, and the latter were distinctly blue in colour. The non-poisoned muscles continued active until forty hours; but when examined at forty-nine hours they were acid and stiff, and did not contract when galvanised. In the poisoned parts, the functions of the motor nerves were destroyed in three hours and ten minutes; the non-poisoned, or right, sciatic continued active until thirty-two hours. It was possible to distinguish the heart's impulse on the thoracic walls, and to determine the frequency of its contractions. During the three days that immediately followed the poisoning, these steadily continued at a rate varying from seventeen to twenty-one; and on exposure, at the end of that time, fifteen feeble beats per minute were occurring. Soon after, the usual irregularities were observed, but the circulation was maintained until eighty-two hours after the injection of physostigma, as the microscope demonstrated. During all this period, the muscles everywhere, except in the tied limb, were flaccid, blue and of alkaline reac-

of muscles from which they had disappeared; and it was then observed that the whole of a muscle seldom twitched at once, but portions of it separately and in succession. I frequently removed a muscle from the dead body, and found that these twitches still continued. In one experiment, where the sartorius had been cut out of a dog, these spasms rapidly followed each other in separate portions of its substance, during ten minutes. Their duration after death varied greatly. Occasionally they ceased before the motor nerves had lost their function, while they frequently continued after their paralysis. The latter effect was well shown in an experiment where seven grains of extract were given to a large dog, by injection into a jugular vein: death, with stoppage of the heart's action and of the respiratory movements, took place in eleven minutes; in twenty-five minutes afterwards, the sciatic nerves were paralysed; and these extraordinary muscular twitches continued for other twenty minutes, or for forty-five minutes after the death of the animal. The central nervous system has no influence in causing or originating these quiverings, for division of a sciatic nerve, before the exhibition of physostigma, did not appear to impede their production. I believe the effect is due to the contact of the poison with the muscular substance itself; and this view is supported by the above facts, and by the circumstance that when a ligature was drawn round the posterior extremity of a rabbit, taking care to exclude the sciatic nerve, the muscles of that limb remained unaffected, after the administration of Calabar bean, while those of the body and of the other extremities were twitching in the usual manner.

Action on the Cerebrum.

A condition of retained consciousness with marked paralysis opposes the idea of the latter symptom being due to coma. Professor Christison has admirably described the coincidence, in his own person, of retained mental vigour with inability for movement. To distinctly prove the absence of any cerebral explanation for this paralysis, a simple experiment was undertaken.

Experiment XVI.

The brain was removed with care from a large frog, and, sometime after this, the animal was found jumping about vigorously.* Two grains of extract, suspended in fifteen minims of

* It appears somewhat startling to assert that complicated movements, of an apparently voluntary character, may continue in frogs after the removal of the brain. I first observed this in an experiment in which the spinal cord had been divided at the base of the skull; and, in describing the condition of the frog in which it was seen, I added a qualifying note ascribing the circumstance to incomplete division of the medulla. Since then, I have occasionally observed the same phenomenon, and the present experiment is conclusive in showing that some of those functions which we are in the habit of ascribing to the cerebral lobes alone, are, in frogs at any rate, shared in by the spinal cord.

May 1867.—Dr Norris enters into this anomaly, and confirms its occurrence, in his admirable paper on Muscular Irritability, in the "Journal of Anatomy and Physiology," No. 2, p. 221, *et seq.* He also refers to Lewes (Physiology of Common Life, vol ii.) as having first prominently announced this curious exception to the generally received views on nerve physiology.

distilled water, were injected into the lower portion of the abdominal cavity. It continued to jump about for four minutes; in five minutes, the first indications of paralysis occurred, at the anterior extremities; and in twenty-five, it was lying flaccid on its belly and chest, without any respiratory movements, but with retained reflex action. The sympoms advanced in their usual order until the complete death of the frog.

An action on the cerebrum cannot, therefore, be the cause of the paralysed condition which is produced. The cerebrum may, notwithstanding, be acted on by physostigma; and the results of several experiments, in which I took various quantities of this substance, appear to favour such an opinion, though, until further investigation, I cannot maintain that the effects produced were not mainly dependent on those perturbations of the circulation which are caused by this poison.

Action on the Spinal Nerves.

1. *Motor or Efferent Nerve-Fibres.*

Experiment XVII.

I injected into the jugular vein of a very large retriever dog, seven grains of extract, suspended in twenty-five minims of distilled water. In three minutes, respiration became gasping; in five, the usual twitching affection of the muscles commenced; and in ten, the dog was lying in a powerless condition. In twenty minutes, respiratory and cardiac action had completely ceased. The right sciatic nerve was then exposed, and galvanic stimulation of its trunk produced vigorous movements confined to the leg whose nerve was stimulated. The same result was obtained when the left sciatic nerve was exposed and stimulated. Both retained their motor conductivity for eight minutes after respiration had ceased; and, for some time longer, the muscles responded to direct galvanic stimulation.

Experiment XVIII.

Five grains of extract were mixed with thirty minims of distilled water, and injected into the abdominal cavity of a large and healthy female cat. Trembling occurred in four minutes, when the cat ran a short distance and fell on her face, after which she lay in any position, flaccid and unresisting. Respiration ceased in ten minutes, but the peculiar twitching of the muscles continued for several minutes longer. The heart was then exposed, and found motionless and full. On galvanising the sciatics, or otherwise stimulating them, the muscles of the posterior extremities contracted vigorously; but no evidence was obtained of the reflex activity of the cord. The sciatic nerves continued active until forty-two minutes after the death of the animal (fifty-two after the administration of the poison); but, when they were galvanised at forty-seven minutes after death, no muscular contraction was produced. The phrenic and brachial nerves also continued active for about the same time.

Experiment XIX.

Three grains of extract, suspended in eleven minims of distilled water, were injected into the subcutaneous cellular tissue in the flank of a full-grown rabbit. Trembling occurred in two minutes, and this continued, with varying strength, until seven minutes; two minutes before which respiration had ceased. The sciatic, phrenic and brachial nerves were galvanised, and found to be active; and such stimulation of the sciatics continued to produce muscular contraction until nine minutes after the cardiac and the respiratory movements had ceased.

Experiment XX.

There was injected into the subcutaneous tissue at the right flank of a rabbit, weighing two pounds, half a grain of extract in fifteen minims of distilled water. The usual tremors rapidly supervened, and in forty-five minutes the animal was dead. During the following thirty-one minutes, galvanism of either sciatic nerve produced contractions of the limb which it supplied.

Experiment XXI.

Half a grain of extract was placed in the mouth of a pigeon. In ten minutes, a profuse flow of saliva and of tears, with occasional passage of fæces, occurred; after which time the bird lay in a helpless condition, with now and then a sudden starting movement. In twenty-four minutes, its respirations had completely ceased. Until eight minutes after death, galvanism of the left sciatic nerve continued to produce movements in the left leg; but in thirteen, the nerve was quite paralysed.

Such experiments were frequently repeated; and in no case did I find that the motor nerves were paralysed before the respiratory movements had ceased, although it has occurred that they have almost immediately afterwards been so. I have found that the interval during which they remain active varies greatly in different animals, and in the same animal according to the dose of poison administered; and I believe that in the latter case the variation is in an inverse ratio. In the rabbit, motor conductivity may be retained for periods ranging from a very few (two or four) to thirty-one minutes. We cannot, therefore, account for either the condition of general paralysis or the cessation of the respiratory movements, which two form the most prominent of the symptoms of physostigma poisoning in warm-blooded animals, by an action on the motor nerves. Experiments XVII., XVIII., XIX., XX. and XXI. are sufficient to prove this. The evidence obtained by experiments with frogs is even more unmistakable. Complete destruction of all the vital functions in this animal never occurred for many hours. In animals of a higher type, the implication of one system so rapidly influences the others that it is often difficult to discriminate between the effects which are caused by the poison and those which are induced as results of the primary action. In the frog, on the other hand, the symptoms advance so slowly from one system to another that it is possible to determine distinctly the sequence of the phenomena which are due to the direct influence of physostigma.

Experiment XXII.

Five grains of extract, suspended in a few minims of distilled water, were injected under the skin over the back of a frog weighing 490 grains. A small quantity escaped in the somewhat vigorous movements which occurred when the frog was liberated. The thoracic respiratory movements ceased in ten minutes, and those of the throat in other four. Twenty-two minutes after the injection, the animal lay on its abdomen in a perfectly flaccid condition; its heart was acting feebly, at the rate of seven per minute; and pinching of the skin anywhere caused but very weak reflected movements. In one hour, no evidence could be obtained by galvanism, or by

any usual irritant, of continuance of the diastaltic function of the cord; but the heart was now contracting nine times in the minute. The sciatic nerves were then exposed; and, on galvanising either of them, movements occurred in, and were confined to, the muscles of the limb whose nerve was so stimulated. Both nerves continued to give this evidence of the conductivity of their motor fibres as long as one hour and thirty-eight minutes after the injection of Calabar bean, or one hour and twenty-four minutes after all respiratory movements had ceased. Shortly afterwards they were found paralysed.

Experiment XXIII.

Into the lower portion of the abdomen of a frog, which weighed 620 grains, a mixture of two grains of extract with ten minims of distilled water was injected. In twelve minutes, the frog was lying in a flaccid condition, and respiration had ceased. In two hours, no reflex movement could be excited. The right sciatic nerve was exposed; and its motor conductivity was found to remain. Galvanism, applied to either sciatic nerve, produced muscular contractions in the limb to which the nerve was distributed, until, but not later than, three hours and twenty-one minutes after the administration of the poison, or three hours and nine minutes after respiration had ceased, and until more than one hour and twenty-one minutes after apparent destruction of the reflex function of the spinal cord. In this experiment, it is important to note, the cardiac action was not greatly affected for more than three hours, as the dose of poison administered was comparatively small.

Experiment XXIV.

Six grains of extract, suspended in fifteen minims of distilled water, were injected into the abdominal cavity of a frog, weighing 350 grains. In eight minutes, no cardiac impulse could be discovered; and the heart was then exposed and found motionless, dark and flaccid. Respiratory movements ceased in eight minutes. It was determined, on irritating the skin with sulphuric acid, that reflex movements could not be obtained two hours and a-half after the injection; but they were produced until nearly this time. *The motor conductivity of the sciatic nerves was retained for twenty-nine hours.*

It thus appears that the motor nerves always remain active after the co-ordinated movements of respiration have ceased, and after the condition of complete and flaccid paralysis has existed for long. On this point, therefore, I cannot agree with HARLEY, who considers that physostigma is a respiratory poison only, and that the early production of asphyxia is caused by paralysis of the motor nerves.*

The protracted interval in the last experiment, between the administration of the poison and the loss of motor conductivity, must be looked upon as a very exceptional one, and as due to the poison having so quickly paralysed the heart that the usual phenomena were not produced. In Experiments XVII., XIX., XXI., XXII., and XXIII., the motor nerves appear to have lost their function sooner than naturally happens in death from cardiac paralysis or from asphyxia. But that they really did so must have remained a mere impression, had it not been that we can, in frogs at any rate, definitely prove a special action on the

* Journal de l'Anatomie et de la Physiologie, 1864, p. 141, *et seq.*; and British Medical Journal, Sept. 3, 1863.

motor nerves, by protecting a portion of the animal from the poison. Such a proceeding cannot be avoided by determining the interval which naturally elapses between the moment of death and the time at which loss of function occurs in these nerves. This interval varies greatly in different classes of animals, and also in different individuals of the same species; and, hence, the data which have as yet been accumulated on this point are not available for such purposes as the present.

Experiment XXV.

The sacrum was excised from an average-sized frog, and, in that manner, the lumbar nerves and the abdominal aorta were exposed. The aorta was ligatured above its bifurcation into the two iliacs, and, immediately afterwards, an average poisonous dose of extract was placed in the frog's mouth. In ten minutes, respiration had ceased; but the frog continued jumping about for other four minutes, when it quietly and gradually subsided on its abdomen and chin. Reflex movements could be excited by irritating the skin anywhere until one hour and seven minutes after the administration; but, for some time before this, a great increase in the strength of the stimulant was required. The skin of the posterior extremities had now become paler, while that of the body, anterior to the ligature, had assumed a much darker colour than it had before the experiment; and the exposed heart was found beating twenty per minute, with regularity and in proper rhythm. The brachial nerve was then laid bare, and was found active; *but this condition ceased two hours and eleven minutes from the commencement of the experiment, and both brachials were then perfectly paralysed.* At this time, weak galvanism applied with closely approximated poles to sections of the spinal cord produced no effect; but when the lumbar nerves below the ligature were galvanised they caused vigorous contractions of the posterior extremities. *On the following morning, this motor nerve activity still remained, in the parts protected from the poison:* but the contractions were now feeble, as muscular rigor was commencing below the ligature; and, in a few hours longer, the muscles separated from the circulation ceased to contract. The muscles of the poisoned portion, in which the motor nerves had been long paralysed, were still quite flaccid, alkaline and irritable; and rigor mortis did not occur in them until the following day.

Experiment XXVI.

The right iliac artery and the right ischiadic vein were tied in a frog, weighing 620 grains; and five grains of alcoholic extract of physostigma, suspended in thirty minims of distilled water, were injected into the abdominal cavity. In twenty minutes, voluntary movements had completely ceased, there were no respirations, and the frog lay in a perfectly flaccid condition. Fifty minutes after the administration of the poison, the left sciatic nerve was exposed. Very weak galvanism of the nerve-trunk caused contractions of the limb; and continued to do so, on occasional observations, till two hours and ten minutes from the commencement of the experiment, or till fifty minutes after the respirations had ceased. In other fifteen minutes, however, the nerve was found to be completely paralysed. The right sciatic nerve, which had been protected from the influence of the poison, by ligature of the blood-vessels of the limb, was examined in a similar manner. *Its motor conductivity continued unimpaired for at least five hours longer than that of the poisoned nerve.*

These are examples of numerous experiments which were undertaken for the special purpose of determining whether Calabar bean has any action on the spinal nerves. They prove undoubtedly that it has the power of destroying their motor conductivity; but it has also been demonstrated that this is not the cause of

paralysis and death in mammals, or of complete loss of voluntary power in frogs. The next question which suggests itself for solution is the somewhat interesting one of the portion of nerve acted on; for, in the case of more than one toxic substance, it has been determined that loss of motor nerve-function does not of necessity imply that both the periphery and nerve-trunk have been affected.

Experiment XXVII.

Immediately after ligature of the left ischiadic artery and vein, two grains of extract were placed in a subcutaneous cavity at the back of an active large frog. Before twenty minutes, respiratory movements had ceased; while the heart was then acting rhythmically, at the rate of thirty beats per minute. One hour after the administration of the poison, the right (or poisoned) sciatic nerve was exposed, and found active; but in other twenty minutes, strong galvanism applied to any portion of its trunk could not produce contractions in the muscles to which it was distributed, and an examination of the brachial nerves proved them also to be paralysed. The left sciatic nerve was, however, perfectly active. When it was galvanised, movements, confined to that limb, were produced in the muscles below (or distal from) the ligatures. *These ligatures were on the thigh; but stimulation of the nerve above them, or of the lumbar nerves on the same side, was followed by energetic muscular contractions below the points of ligature.*

The muscles were everywhere active, and continued so for several days; and those of the non-poisoned limb were the first to pass into rigor mortis. The sciatic nerve of the non-poisoned limb, and the lumbar nerves of the same side, continued active for many hours; but their loss of function occurred several hours before that of the muscles below the ligatures.

This evidence, which has been frequently confirmed, is in favour of the view that the motor paralysis caused by physostigma is due to an action on the nerve endorgans, or peripheral terminations, and not to one on the trunk. We may obtain even more distinct proof, by a slight modification of this experiment.

Experiment XXVIII.

An incision was made down the centre line in the right posterior extremity, from the back of the knee to the ankle, of a frog, weighing 876 grains; and in this way the gastrocnemius muscle was completely exposed. It was carefully dissected from its connections, excepting that its origin and insertion, and the nerve fibres entering it, were untouched. All its blood-vessels were ligatured, and the cut through the skin was closed by sutures.

Immediately after the above operative procedure, three grains of extract, in fifteen minims of water, were injected under the skin of the back. Reflex movement could not be excited an hour and five minutes afterwards, while the heart still continued to contract. Both sciatic nerves were then exposed. Galvanism of the left produced no contraction; while galvanism of the right caused energetic movements of the limb, which, moreover, did not extend to the toes. Five hours after the administration of the poison, this condition continuing, the left gastrocnemius was exposed, and the right again laid bare by cutting the sutures. Galvanism of the right sciatic demonstrated visibly contraction of the right gastrocnemius, but of no other muscles of that limb; and no result followed stimulation of the left sciatic, although the left gastrocnemius muscle contracted vigorously when the poles were applied to its surface.

It is thus shown that some of the endorgans of a motor nerve may have their conductivity destroyed while others remain active during the retained

vitality of the nerve trunk, and that this contrast in condition depends on the access or not of the poison—a clear demonstration of the power of physostigma to paralyse the nerve terminations. This action has been hitherto overlooked.

Calabar bean is, therefore, now added to that very limited class of neurotic agents which affect the motor endorgans. Indeed, only two substances, as far as I am aware, were previously known to possess this remarkable action. For a considerable time after the brilliant, and perhaps unequalled, researches of CLAUDE BERNARD,* curare stood alone as such a substance: when KÖLLIKER discovered that conia has a similar action;† and his observations have been recently confirmed by GUTTMANN.‡

Physostigma is, however, peculiar in the method in which it so acts; a very prolonged contact with the nerve terminations, and a long continued circulation of poison-bearing blood, being apparently necessary. In warm-blooded animals, this paralysis of the motor endorgans may, therefore, be easily overlooked; but in frogs, with localised poisoning, it is conspicuously displayed, as in the experiments which have been given.

It is interesting to remark the different conditions which are produced in the functional vitality of nerves and muscles when physostigma is administered to a frog after the vessels of one of its limbs have been ligatured.

Experiment XXIX.

Immediately after ligaturing the right ischiadic artery and vein of a frog, which weighed 609 grains, two grains of extract, in fifteen minims of distilled water, were injected into the subcutaneous tissue of the back.

One hour and twenty-five minutes afterwards, the heart was found beating seventeen times per minute.

The two gastrocnemii muscles, with their femur attachments, and a portion of each of these bones, along with the sciatic nerves from their terminations in the gastrocnemii to the lumbar plexus, were then removed. These parts were so arranged, that an interrupted current from one DANIELL'S cell and DU BOIS REYMOND'S induction apparatus, could be transmitted simultaneously through either both nerve trunks, or both muscles, by the turn of a key.

a. Examination of the Nerves (one hour and fifty-four minutes after the administration of the poison).—The galvanic current was first passed through the sciatic nerves. Distinct tetanus of the non-poisoned muscle was caused when the secondary coil stood at 63° on the scale; the poisoned was at perfect rest. The current was gradually strengthened by advancing the secondary coil; when this reached 53°, but not before, the poisoned muscle was thrown into tetanus.

b. Examination of the Muscles.—Immediately afterwards, the current was passed directly through both muscles. The poisoned gastrocnemius contracted when the secondary coil reached 63°; the non-poisoned did not do so until this was advanced to between 52° and 53°: that is to say, the poisoned muscle was thrown into tetanus by a weaker current than was required to produce the same effect in the non-poisoned muscle.

* Leçons sur les Sub. Tox. &c., 1857, pp. 238–413.

† Verh. d. phys.-med. Ges. zu Würzburg, 1859, vol. ix., part 2, p. 55, *et seq.*; Virchow's Archiv. x., p. 235; and other papers.

‡ Berliner Klin. Wochenschr., No. 5–6, 1866. Quoted in RUTHERFORD'S Report on Physiology; Journal of Anatomy and Physiology, No. 1, 1866, p. 155.

Experiment XXX.

A similar experiment was performed on another frog, also poisoned with two grains of extract, but weighing only 464 grains.

a. Examination of the Nerves (two hours and twenty minutes after the injection).—The galvanic current was passed along portions of both sciatic nerves simultaneously. When the secondary coil reached 52°, the non-poisoned gastrocnemius was thrown into tetanus, the poisoned remaining inactive. It was then slowly advanced; and at 30°, faint contractions occurred in the poisoned gastrocnemius, of a partial character, as if only a few muscular bundles, and not the whole muscle, were contracting, and which continued for a few seconds only, and did not recur although the secondary coil was advanced, after an interval for rest, to 0° (the strongest current from this arrangement). The stimulus was then applied to the trunk of the non-poisoned nerve above the position of the ligatures, and, therefore, where it must have been in contact with the poison; contraction again occurred when the secondary coil was at 52°.

b. Examination of the Muscles.—When the secondary coil reached 55°, tetanus was produced in the poisoned gastrocnemius; and at 54°·5, the non-poisoned muscle was thrown into tetanus.*

It would thus appear that motor nerve excitability or conductivity is diminished and then destroyed by physostigma (this change being produced at the endorgans), while retained for a long time thereafter in those parts of the same animal which have been guarded from the access of the poison. It is also seen that the effect on idio-muscular contractility is exactly converse; that property being uninjured by the mere presence of physostigma, while diminished and destroyed by stoppage of the circulation.

It is usually asserted that division of a nerve, previous to the exhibition of any substance that affects its vitality, is a sufficient method for determining the position of its primary implication, and, therefore, sufficient for determining the direction in which this extends. This proceeds upon the supposition that when it is the nerve trunk near its origin that is first affected, extension of the poisoned condition to the distal portion will be delayed by intermediate division of the nerve. BERNARD attempts in this way to prove that the primary paralysis of the motor nerve endorgans by curare extends from them, along the trunk of the nerve, towards the cord.† The paralysis of the motor nerves after strychnia is said to proceed in a direction exactly the reverse,—from the origin to the periphery.‡ It appeared of some interest to examine this question with Calabar bean, for with it we would not expect that previous division of the trunk should delay the implication of the nerve endorgans, as this precedes the paralysis of the trunk.

Experiment XXXI.

I exposed the two sciatics of a frog for a short distance, and both equally, and divided the left nerve with a very sharp pair of scissors. A fatal dose of Calabar bean was then administered. When reflex movement could no longer be excited (one hour and two minutes after the administration), the right sciatic was galvanised; but no contractions were caused. The left was stimulated, at the cut extremity of its distal portion, with the same current, and active movements of the left leg and toes followed. The galvanism was repeated, at intervals of five minutes,

* In Experiments XXIX. and XXX. I have thankfully to acknowledge the valuable assistance I obtained from Dr RUTHERFORD.

† *Loc. cit.*, p. 312. ‡ *Ibid.*

for other twenty minutes; with the same negative result in the case of the uncut nerve, and with continuation of activity in the cut one. The energy of the contractions then gradually diminished; but the distal portion of the cut nerve was not paralysed until twenty-eight minutes after the loss of motor nerve conductivity in the portion of its trunk proximal to the spinal cord, as well as in all the other nerves of the body.

Experiment XXXII.

In a second experiment, the distal portion of the divided nerve retained its conductivity forty-five minutes longer than the undivided nerve.

Another experiment contains some further results, which are worthy of being shortly mentioned.

Experiment XXXIII.—(*Temperature of Laboratory*, 56° *F.*)

Performed in August 1866.

I exposed a small and equal portion of each sciatic nerve in a frog weighing 515 grains, and cut through the right nerve-trunk. One grain and a-half of extract was then injected into the cellular tissue under the skin of the back.

In one hour and thirty minutes, no variety of stimulation could excite reflex movements: and when the left, or uncut, sciatic was then gently galvanised, faint contractions of the left toes were all that was produced; while the same interrupted current caused vigorous contractions when applied to the distal portion of the cut nerve. This condition continued, the contractions produced by the left (uncut) nerve becoming gradually fainter, until three hours and twenty-two minutes after the poison had been injected, when this nerve became perfectly paralysed, as well as all the other motor nerve fibres and the proximal portion of the cut sciatic. The distal portion of the cut (right) sciatic seemed all this time quite unaffected; and when it was galvanised, the muscles with which it was connected contracted with vigour. This condition lasted for fifteen minutes, *when galvanism of the uncut nerve again produced a faint twitch of several of the left toes.* By-and-by, it recovered all its former activity, and the return to vitality was shared in by the other temporarily paralysed nerves. On the following morning the frog was perfectly well and jumping about.

From such data it cannot be concluded that the motor nerve fibres are paralysed by a centripetal progression of the poison. There seems only to be a connection between the rapidity of paralysing effect, on the one hand, and the subdivision of nerve substance with facility of contact of poison, on the other; as the motor trunks were undoubtedly affected when it was impossible that they should be influenced by an extension of the poisonous action from their endorgans. I cannot advance any very satisfactory explanation of this delay in the action. Probably it is caused by the irritation of the vaso-motor nerves in the trunk of the sciatic, which the section of the latter at first produces, and which is followed by contraction of the capillaries in the parts supplied by them.* During this contraction, a much smaller quantity of poison-bearing blood is brought in contact with the endorgans of the cut than with those of the uncut nerve, and, as a very prolonged contact of the poison appears necessary, this may be sufficient to account for the delay; while the recovery from the irritation of the section, which soon

* Such contraction has been directly demonstrated by LISTER and others after division of the sciatic nerve. See "An Inquiry regarding the parts of the Nervous System which regulate the contraction of the Arteries;" Philosophical Transactions, 1858, vol. cxlviii., p 607.

occurs, again allows of a free circulation and of consequent paralysis of the motor endorgans of the divided nerve.

2. *Afferent Nerve Fibres.*

The discussion of the influence that those fibres in the spinal nerves that conduct impressions to the cord exert in producing paralysis, will be a short one, as it can be readily shown that their effect is negative. It will be sufficient to notice that in mammalians it was always possible to obtain evidence of their activity as long as the functions of the spinal cord were retained, and that, therefore, they were in no wise concerned in the production of the general flaccidity and loss of motor power which is caused by Calabar bean. The same evidence was obtained in frogs, and could in them be distinctly shown by localization of the poisoning. In place of the function of these nerves being lessened, I believe that it is generally increased, so that movements may be excited more readily after the action of the poison than before it.

Experiment XXXIV.

I tied the right ischiadic artery and veins of a frog weighing 573 grains, and suspended it by the lower maxilla. Soon after, a silk thread was drawn over various parts of the skin, including the right leg, without exciting any reflex movement. On dipping the feet, separately, into dilute sulphuric acid (five minims of oil of vitriol to twelve ounces of water) reflex movements occurred with each, after 80 beats of a métronome set at 100 in the minute. I then injected into the abdomen two and a-half grains of extract in fifteen minims of water. In one hour and three minutes, on the left foot being dipped into the acid, reflex movements occurred in the right in 190 beats of the métronome; but no movement followed in the left limb in 200 beats, nor when the poisoned foot was placed in stronger acid (10 min. to 12 oz.), while this caused energetic contractions of the non-poisoned portion of the right limb. The reflex activity of the spinal cord was, therefore, very greatly diminished, and still the afferent nerves continued active. The silk thread which was formerly employed was now drawn over the skin of the right leg below the ligatures, and, as before, it produced no diastaltic movement. *On applying it, however, to the skin of the left leg and of the other poisoned regions, twitches constantly occurred in the toes of the right leg, and only occasionally, and of a very feeble character, in the poisoned region.* This was repeated, at intervals, during the next ten minutes, with the same result. After this, the thread ceased to excite diastaltic movements; but the spinal cord had now lost its vitality, and no movement could be produced even when it was directly galvanised.

The afferent nerve fibres, in this experiment, retained their original activity longer than the efferent, and at least up to the time at which they could not be tested, because of the loss of the diastaltic function of the spinal cord. The increase of excitability in the afferent fibres, where these had been acted on by blood conveying physostigma, cannot be due, in the slightest degree, to any spinal cause, for the effect did not occur in the right leg, to which access of the poison had been cut off by ligature. Besides, measurement of the rapidity with which reflex movements followed the application of a stimulus to either poisoned or non-poisoned parts gave such proof of marked depreciation having occurred before the afferent excitability had been increased as is sufficient of itself to eliminate any spinal influence.

Action on the Spinal Cord.

Having now excluded the encephalon, muscles and spinal nerves, we are led to conclude that the production of the paralysis by physostigma is due to an action on the spinal cord. Such an opinion was originally expressed by myself after a careful general consideration of the symptoms, but no subsequent investigator has coincided with my theory except Laschkewich,* from whose excellent paper I have derived more than one hint for the further and special examination of the spinal effects of Calabar bean.

I quote the following experiment from my previous paper on this subject, as it affords an excellent example of those general paralytic symptoms that first induced me to refer the principal neurotic action of physostigma to the spinal cord.

Experiment XXXV.

"Five and a-half grains of the fine powder of the kernel were made into pills, and swallowed by a buck rabbit, eight months old.

"A slight degree of paralysis was seen in the posterior regions, in ten minutes, and, soon after, they yielded, the anterior portion of the trunk remaining supported by the fore-limbs. In fifteen minutes, the fore-legs gave way, and fæces were passed. In twenty minutes, the respirations became noisy, reflex action was not abolished, and the pupils contracted. In thirty minutes, the rabbit submitted to be placed in any position. In thirty-five minutes, the respirations became extremely noisy, and accompanied with muscular spasm. Fæces and urine were passed, and reflex action could not be induced by puncturing the skin. General, but slight, muscular spasms now occurred frequently; the eyelids did not contract when the eyeball was pricked, and the respiratory stertor ceased. In forty minutes, a general spasmodic contraction of the muscles occurred, and, in forty-one minutes, all respiratory movement had ceased.

"*Autopsy*, immediate. The cut muscles contracted. The heart was acting at the rate of seventy-two per minute; and this ratio gradually diminished till it ceased, thirteen minutes after death. The brain was rather darker than usual, and no change could be perceived in the spinal cord. The cerebro-spinal fluid was in abnormal abundance. The large veins were distended, and the right chambers of the heart were engorged with dark blood. . . . The vermicular action of the intestines was well marked, and all the viscera contained an abnormal excess of dark blood. The muscular system was flaccid, but contractions could be caused by irritation of the nerves."

This experiment formed one of a series undertaken to discover the smallest dose which could produce death in a full grown rabbit.† The quantity employed, five and a-half grains of the kernel, was the smallest that could do so.

As evidence of the same character, I add the following from many subsequent experiments:—

Experiment XXXVI.

One grain and a-half of extract, suspended in fifteen minims of distilled water, was injected into the abdomen of a small collie dog. The animal was rapidly affected with inability to

* Virchow's Archiv. Februar, 1866.

† *Op. cit.* sect. v. experiment viii.

stand, tremors, lachrymation, defæcation and urination; and in eleven minutes all respiratory movement had ceased. The spinal cord was immediately exposed, but the strongest galvanism, consistent with localisation of the current, applied to various portions of its substance, failed to excite any movement of the body. A sciatic nerve was then exposed; and slight stimulation of it produced vigorous contractions of the limb, but no reflex movement. Lastly, the thorax was opened; and the heart was found contracting thirty-two times in the minute, in perfect rhythm and with regularity, although the diastolic pause was somewhat prolonged. Thirty-nine minutes after death, the cardiac beats were ten per minute, and the sciatic and other nerves could still transmit excito-motory impressions to their muscles.

Such data are sufficient, after the former results, to prove the action of Calabar bean on the spinal cord of mammalians, as far as it is possible to do so. Where larger doses are given, the evidence is not so distinct; as, along with complete loss of reflex function, the heart is found paralysed at death; and it is well known that, in the animals in question, stoppage of the circulation is rapidly followed by loss of reflex function. Still, from the above, and from other experiments which will follow, it can be conclusively proved that physostigma has a special and primary action on the cord.

Experiment XXXVII.

Performed December 1866.

After tying the left femoral artery and vein of a frog, weighing 430 grains, I injected two grains and a-half of extract into the cellular tissue of the back. In an hour and twenty-two minutes, the reflex function of the cord, as tested by stimulation of the skin by galvanism and by sulphuric acid, was completely destroyed; but the exposed heart was found acting regularly and rhythmically, though only at the rate of twelve beats per minute. The two gastrocmenii muscles, with their attached sciatic nerves, and the portions of femur into which these muscles are affixed, were then removed. The poisoned nerve and muscle were arranged in the usual manner on DU BOIS REYMOND'S modification of HELMHOLTZ'S myographion—an apparatus designed to measure the rates of conduction along nerve fibres. The curved lines produced by stimulation of two portions of the nerve, differing in length by one inch and a-half, were found to correspond so exactly that the period during which the impression travelled over the one inch and a-half of poisoned nerve could not be measured. The non-poisoned nerve gave the same result.

This experiment was undertaken to determine whether physostigma gradually lessens the rate of conduction in motor nerves, as curare is stated to do.* It was worthless to answer this question, as was also another immediately afterwards performed with the same result; for the frogs employed were in too irritable a condition: but its value is evident in considering the action of physostigma on the spinal cord. *For the diastaltic function of the spinal cord was completely destroyed, while the poisoned and non-poisoned motor nerves were in so equally active a condition, that the difference between the times in which impressions travelled along two portions of the same nerve, differing in length by one inch and a-half, could not be measured in either, even by a delicate instrument specially adapted for this purpose.*

* A. VON BEZOLD; Monats Bericht der Berlin: Akad. 1859.

In the further investigation of the effect on reflex movements, there is no process which yields so conclusive results as that in which frequent measurements are made of the interval that elapses between the application of a stimulant to the extremity of an afferent nerve and the resulting reflex contraction.*

Experiment XXXVIII.

The spinal cord was divided at the occiput of a frog, weighing 460 grains. It was suspended by the lower jaw, and the reflex activity tested by dipping the web of both posterior extremities into dilute sulphuric acid (ten minims oil of vitriol to twelve oz. of water). The exact time which elapsed between the contact of the foot and the resulting reflex movement was ascertained by the beats of a métronome, set at 100 in the minute. Before the administration of the poison, the reflex movement occurred in twelve beats. Two grains of extract, in water, were injected into the abdomen.

In	5 minutes,	reflex movement occurred in	15 beats.
	10 „	„	31 „
	15 „	„	40 „
	20 „	„	57 „
	25 „	„	69 „
	30 „	„	82 „
	35 „	„	106 „
	40 „	„	134 „
	45 „	„	165 „
	50 „	„	181 „
	55 „	„	192 „
	1 hour 5 min.	no reflex movement after	250 „
	1 „ 15 „	strong acid caused no movement.	

The sciatic nerves were then exposed; and weak and carefully localised galvanism applied to either trunk caused energetic contractions of the limb below the portion stimulated, which could be obtained until two hours after the injection of the poison.

It seemed important to ascertain the coincident changes that take place in the heart's action; and for this purpose several experiments were undertaken, of which the following is an example. By a slight adjustment of the frog's body, the cardiac impulses are easily seen and counted.

Experiment XXXIX.

A frog, weighing 460 grains, was suspended by its lower jaw. The average of the cardiac contractions, during ten minutes, was forty-five per minute. The two feet were alternately stimulated, every five minutes, by contact with dilute sulphuric acid (10 minims of oil of vitriol to 12 oz. water); a vessel containing the acid being gently raised so that the fluid covered the whole foot. A métronome, set at 100 in the minute, was employed to determine the interval between the application of the irritant and the resulting reflex movement.

* This method of examining reflex activity seems to have been first recommended by Von Türck in 1850 (Ueber den Zustand der Sensibilität nach theilweiser Trennung des Rückenmarks); and its value has been brought more prominently into notice by Dr J. Setschenow (Physiologische Studien über die Hemmungs-mechanismen für die Reflexthätigkeit des Rückenmarks im Gehirne des Frosches, Berlin, 1863).

15 minutes before poisoning, the right foot was drawn up in 13 beats.
10 „ „ left „ „ 11 „
5 „ „ right „ „ 9 „

Two grains of extract, in 15 minims of water, were now injected into the subcutaneous tissue of the back.

In 5 minutes,	the left foot	was drawn up in	14	beats.		
10 „	right „	„	22	„		
15 „	left „	„	36	„	the heart contracted per minute,	36
20 „	right „	„	28	„		
25 „	left „	„	39	„	„	18
30 „	right „	„	52	„		
35 „	left „	„	49	„	„	18
40 „	right „	„	72	„		
45 „	left „	„	60	„	„	17
50 „	right „	„	76	„		
55 „	left „	„	88	„	„	15
1 h. & 0 min.	right „	„	99	„	During this interval, the heart's impulse could not be counted, but the frequency of its contractions was probably much lower than 15 per minute.	
1 „ 5 „	left „	„	115	„		
1 „ 10 „	right „	„	111	„		
1 „ 15 „	left „	„	138	„	the heart contracted per minute,	16
1 „ 20 „	right „	„	169	„		
1 „ 25 „	left „	„	186	„	„	20
1 „ 30 „	right „	„	192	„		
1 „ 35 „	left „	twitched slightly in	230	„	„	20

After this, no reflex movement occurred when either foot was dipped in much stronger acid; but galvanism applied to the exposed sciatics caused vigorous movements, which occurred only in the limb whose nerve was stimulated. The cardiac contractions, in half an hour, became as frequent as twenty-five per minute; and, on the following morning, the thorax was opened, and rhythmical contractions were perceived, at the rate of twenty-four per minute. A microscopic examination was at this time made of the web, and a circulation was discovered in its capillaries.

A few experiments were undertaken in order to eliminate the possible effect of Calabar bean on the motor nerves in producing this gradual depression of reflex activity.

Experiment XL.

The femoral artery and vein in each posterior extremity of a frog, weighing 540 grains, were ligatured, and the animal suspended by the lower maxilla. Both feet were simultaneously dipped in dilute sulphuric acid (10 min. of oil of vitriol to 12 oz. of water); and the interval between the contact and the resulting reflex movement was measured, as before, by the beats of a métronome.

15 minutes before the poison was injected, reflex movement occurred in 10 beats.
10 „ „ „ 9 „
5 „ „ „ 11 „

I then injected three grains of extract, in ten minims of water, under the skin of the back.

In 10 minutes, reflex movement occurred in 28 beats.
20 „ „ 24 „
30 „ „ 71 „

In 40 minutes, reflex movement occurred in 80 beats.
50 „ „ 101 „
1 hour and 5 minutes „ 118 „
1 „ 15 „ „ 136 „
1 „ 20 „ „ 150 „
1 „ 30 „ „ 200 „
1 „ 40 „ no movement in 200 „

A stronger acid was substituted (20 min. to 12 oz.).

In 1 hour and 50 minutes, reflex movement in 111 beats.
2 hours 0 „ „ 160 „
2 „ 10 „ „ 173 „
2 „ 20 „ „ 198 „
2 „ 30 „ no reflex movement in 220 „
2 „ 35 „ strong acid caused no reflex movement.

The heart was exposed; and it was found contracting in proper rhythm, nineteen times per minute. The sciatic nerves were active.

On the following day, the heart was contracting twenty times per minute; and galvanism of the sciatic nerves caused feeble muscular contractions in the posterior extremities, but no diastaltic movement. The frog ultimately died.

Experiment XLI.

After ligature of its left femoral artery and vein, a frog, weighing 495 grains, was suspended as in the previous experiments. The reflex activity was tested with the following result:—

Métronome, 100 to 1 minute; acid = 5 min. to 12 oz. water.

At 20 minutes before poisoning, the left leg was drawn up in 24 beats.
15 „ „ right „ „ 19 „
5 „ „ left „ „ 28 „

Three grains of extract, in water, were then injected subcutaneously at the back.

In 5 minutes, the right leg was drawn up in 24 beats.
10 „ left „ „ 30 „
15 „ right „ „ 36 „
20 „ left „ „ 56 „
25 „ right „ „ 72 „
30 „ left „ „ 90 „
35 „ right „ „ 150 „
40 „ no movement when either foot was kept in contact with the acid during 200 beats.

A stronger acid was substituted, of the strength of 10 minims of oil of vitriol to 12 oz. of water.

In 45 minutes, the right leg was drawn up in 89 beats.
50 „ left „ „ 104 „
55 „ right „ „ 108 „
1 hour left „ „ 172 „

A still stronger acid, 20 minims to 12 oz., was now used.

In 1 hour 5 minutes, the right leg was drawn up in 85 beats.
1 „ 10 „ left „ „ 118 „
1 „ 15 „ right „ „ 138 „
1 „ 20 „ left „ „ 140 „

In 1 hour 25 minutes, the right leg was drawn up in 145 beats.
1 „ 30 „ left „ „ 158 „
1 „ 35 „ right „ „ 160 „
1 „ 40 „ left „ „ 180 „
1 „ 45 „ right „ „ 197 „
1 „ 50 „ no reflex movement of either after 250 „ *

Both sciatic nerves were found to be active when directly stimulated, but the contractions were confined to the limb whose nerve was galvanised.

This, and the experiment which precedes it, are conclusive in showing that the diminution, and then destruction, of the diastaltic function are not interfered with when physostigma is only prevented from acting on peripheral portions of the reflex apparatus. When, however, it is permitted to act on the nerve endorgans, but is prevented from reaching the centres, the effect is very different.

Experiment XLII.—(*Temperature of Laboratory*, 53° *F.*)

I opened the abdomen of a frog, and, with great care, tied, and, in some instances, cut through, all the blood-vessels that entered the spinal canal from the lower edge of the scapula to the coccygeal extremity of the sacrum, and then divided the spinal column at the higher of these points. By this means, the blood was only prevented from reaching a limited portion of the cord; so that, though unable to convey physostigma to the reflex centre for the posterior extremities, it could still do so to those extremities themselves, and to all other parts of the body. Voluntary movements of the limbs and of the body, anterior to the divided portion of the cord, occurred when the frog was set free; and irritation of the posterior parts was promptly followed by reflected movements confined to them. The heart, which the operation had partially exposed, was contracting sixty-eight times per minute.

A large dose of extract was administered by the mouth. In twenty minutes, only very faint reflex movements could be excited when the anterior feet were irritated, while gentle stimulation of the posterior caused energetic reflex movements; and the heart was acting at the rate of eighteen per minute. In little more than an hour, the diastaltic function was completely abolished in the anterior half of the body, while the conductivity of the brachial nerves remained; and, still, a slight pinch or weak galvanism of the posterior webs was followed by pretty active reflex movements. The heart had now stopped. *The diastaltic activity of the posterior half of the body continued for two hours after it had disappeared in the anterior.*

The mere prevention of the access of physostigma to a segment of the cord, while it was allowed to act directly on all other parts of the body, had, therefore, the effect of delaying the loss of reflex function in the parts connected with that non-poisoned segment. We have, already, frequently seen that protection of the endorgans and of portions of the nerve trunks from the poison does not delay or at all influence the gradual impairment and final destruction of the reflex function that ensue on its access to the cord. The conclusion is only logical, that Calabar bean produces a destruction of the diastaltic power by an action on the spinal cord.

It is not superfluous to observe that I do not in these experiments ignore the effect on the cord of mere stoppage of the circulation. When the heart is quickly

* In all these experiments, the parts which had been dipped in the acid solution were immediately washed with distilled water. The destructive action of the acid was thereby reduced to a minimum.

paralysed, as frequently happens, reflex movement will, on that account alone, be soon impossible. Experiments in which the heart is so affected are nearly worthless as far as the investigation of the spinal action of physostigma is concerned, and it would be needless to detail them. With the object of bringing forward as clear evidence as possible on this subject, I have selected experiments in which the cardiac action was only impeded, and in which it continued after the abolition of reflex power.

It is well known that strychnia causes an exaggeration of the reflex activity. Whether this is produced by an action on the spinal centre, or by one on the afferent nerves, is yet a question in dispute;* but it is obvious that a substance that diminishes this function at the cord, will also diminish the reflex activity consequent on the administration of strychnia, whatever be the special part of the reflex circle affected by that administration. Such a result is produced by physostigma, and therefore, adds to the many proofs of its spinal action.

Experiment XLIII.

I placed a small drop of solution of strychnia (Brit. Pharm.) on the back of a frog. This produced tetanus in four minutes; when a considerable dose of physostigma extract was inserted into the animal's mouth, the manipulations necessary for which excited a series of violent emprosthotonic spasms. Four minutes after the Calabar bean was exhibited, a decided diminution occurred in the frequency and severity of the convulsions; and, in nine minutes, they had lost their tetanic character. In forty minutes, it was difficult to excite even a faint reflex movement by pretty strong galvanism of any part of the body; and, soon after, reflex action had completely disappeared, even when the exposed sciatic nerves were galvanised.

By comparing the last experiment with one in which the strychnia effects were not interfered with, it is easy to show what part the Calabar bean played in thus interfering with the peculiar action of strychnia.

Experiment XLIV.

A frog was selected of the same weight as the last, and in every other respect as nearly resembling it as possible, and a small drop of solution of strychnia (Brit. Pharm.) was placed on its back. Tetanus occurred in four minutes; and violent convulsions of a tetanic character followed each other at intervals, and could be excited by the slightest touch, during the next six hours, after which the observations were stopped.

This evidence may be still further increased, if we produce well-marked paralysis by physostigma and then administer strychnia without causing its peculiar action.

Experiment XLV.

A frog was selected of the same weight as those employed in the two preceding experiments, and a dose of extract of Calabar bean was inserted under the skin of its back. This acted with considerable rapidity, so that, in twelve minutes, respiratory and voluntary movements had ceased, and reflex action was sluggish. A small drop of solution of strychnia (Brit. Pharm.) was then placed on a wound made through the skin of the back. Twenty minutes after this, reflex movement could still be excited; but during all this time no tetanic convulsion, nor even exaggeration

* Marshall Hall, Brown-Séquard, Bonnefin, Martin-Magron and Buisson maintain that strychnia causes tetanus by an action on the spinal cord; Claude Bernard and Stannius are the principal champions of the opposing theory of its action on the sensory nerves.

of reflex action, had occurred. Thirty-eight minutes after the strychnia had been applied, the diastaltic function had disappeared, though galvanism of the exposed sciatics still caused muscular contractions, and though the heart was beating at the rate of twenty-eight per minute.

The subject of opposing physiological actions has been a favourite one with many writers on poisons, and "antagonistic" effects have been largely discussed, as might be expected from their interest and practical applications. Nicotia,* aconitia† and curare‡ have been proposed as counter agents to strychnia, and atropia has been proposed as one to morphia.§ Calabar bean has been, before now, pointed out by myself and others as an opponent in action to strychnia; and, as with curare, its application to the treatment of tetanus has been recommended. I believe that no other drug so directly diminishes reflex action, and is, therefore, so likely to be employed with advantage in tetanus, as physostigma. Curare opposes spasm by paralysing motor nerves, nicotia by destroying muscular contractility; but physostigma attacks (if we may use the word) the spinal cord which is necessarily implicated as the centre of every diastaltic action. There seems to be no reason why it should not always prove a certain cure in traumatic tetanus. Its success in strychnia poisoning will probably depend on the quantity, in relation to the case, that has been administered; as this poison may be considered to have two fatal doses—a smaller, where death is caused by asphyxia or exhaustion, and a larger, where, even if its tendency thereto by asphyxia or exhaustion shall be averted, it will still certainly occur, by the special action of the poison on the histological structures it attacks.‖ Such a substance as Calabar bean may be employed with advantage to prevent death after the administration of the smaller quantity.

Physostigma has lately been proposed as a physiological antidote for atropia poisoning; and KLEINWÄCHTER has had the courage to employ it for this purpose, principally on the ground of its anti-mydriatic property.¶ As will be afterwards shown, these two substances appear to act in opposite modes on the ganglionic system of the blood-vessels; but the nature of their effects on the cerebro-spinal system is such as to make it irrational to anticipate any success in their employment as counter-agents.

* Rev. SAMUEL HAUGHTON, Dublin Quarterly Journal of Medical Science, August 1862.

† E. WOAKES, British Medical Journal, October 1860, &c.

‡ HARLEY, Lancet, 1856; L. VELLA, Comptes Rendus, 1860; CLAUDE BERNARD (opposes the view of counteraction), Leçons, &c., p. 377.

§ GRAVES, Clinical Lectures on the Practice of Medicine; ANDERSON, Effects of Belladona in Poisoning by Opium, 1854; LOPEZ, American Medico-Chirurgical Review, vol. iv. 1859; Dr W. F. NORRIS, American Journal of Medical Science, Oct. 1862; CAMUS (experimentally disproves this asserted antagonism), Gazette Hebdr., 11 Août 1865, and Canstatt's Jahresbericht, &c., Fünfter Band, 1866, p. 123.

‖ It has been found that frogs, after fatal doses of strychnia, may die *without any convulsions*, if care be taken to protect them from all causes of excitation—MARSHALL HALL, Aperçu du Système Spinal, p. 170; CLAUDE BERNARD, Lectures on Experimental Pathology and Operative Physiology, Medical Times and Gazette, 1860, v. ii., p. 25.

¶ Berliner klin. Wochschr, 38, 1864.

To argue from pupil effects alone of an antagonism between the actions of morphia and atropia, I believe to be absurd, while we know almost nothing of how iridal changes are produced by poisons. We shall never have antidotes to active substances until we can produce within the body chemical changes in their composition of such a nature as shall render them inert. By originating a secondary, and apparently counter, action, we may sometimes ward off death; but only where that would have been due to one of the symptoms of a small dose: we do not prevent the fatal action on the tissues of a large dose; and we run the risk of adding a second active substance, which cannot produce any effect without causing a tissue change, and which may, therefore, hasten and render more certain a previously doubtful, fatal result.

The most conspicuous symptom that is caused by physostigma is paralysis; and this necessarily depends on an effect produced on the nerrous system, or on the muscular system, or on both. I believe this investigation is sufficient to show that it is due not to an action on the cerebral lobes, on afferent or efferent spinal nerves, or on muscles, but to one on the spinal cord, as a reflex centre. This spinal affection is the result of a primary and special action of Calabar bean; but it is more or less favoured by a simultaneous depression of the heart's action, as will be more conveniently illustrated in the special examination of the cardiac effects.

Action on the Heart.

The heart is affected in a marked manner by Calabar bean; and this has a more or less direct influence in causing death, according to the dose that may have been exhibited. With a large dose, the animal dies by cardiac syncope. With a smaller one, the heart beats are only diminished in frequency, and, as the circulation continues, the spinal cord is more and more affected, until its diastaltic function is destroyed and asphyxia caused. The latter effect is proved in the previous portion of this investigation, and it will be sufficient for the purpose of illustrating the former to quote one of my already published experiments with warm-blooded animals.

Experiment XLVI.

"The skin was raised in the left flank of a large black-and-white female cat, the needle-point of Wood's hypodermic syringe was inserted into the subcutaneous cellular tissue, and ten minims of a syrupy extract were injected" (equivalent to about four grains of the preparation usually employed in this investigation).

"In two minutes, trembling occurred; and, in three, the cat fell. Fluid escaped from the mouth, the pupils contracted, and urine was voided. In five minutes, the respirations became hurried, noisy and laboured. Reflex action could not be excited by severe stimulation, nor did the eyelids contract on irritation of the conjunctiva. The animal became perfectly flaccid, the only symptom of life was an occasional gasp, and this ceased entirely, seven minutes after the administration.

"*Autopsy*, immediate. The pupils were observed to dilate. A few contractions occurred in the muscles that were cut. *The heart was perfectly quiet, and without the slightest action.* . . . . On removing the pericardium, irregular movements occurred in the heart, and a partial contraction could be produced by irritation, fifteen minutes after death. The vessels of the

thorax and abdomen were well filled, and could be readily distinguished by the colour of their contents. On incising the left ventricle, blood of the usual arterial hue escaped; and on incising the right, dark blood appeared. Both were allowed to run side by side, when the contrast was distinctly shown."*

We have now to describe the various changes that are undergone by the heart before its contractions finally cease, and to examine the mechanism by which these changes are produced. For the former purpose, several experiments were performed on frogs whose hearts were exposed before the administration of the poison.

Experiment XLVII.—(*Temperature of Laboratory*, 58° *F.*)

A large frog, which weighed 730 grains, was fixed down on its back in such a manner that the circulation in the limbs was not to any extent impeded; and the heart was exposed by the removal of a portion of the sternum. This operation can easily be performed without injuring any large blood-vessel, and, indeed, without causing any loss of blood further than a temporary oozing from the cut surfaces. A few minutes afterwards, its heart-beats were frequently counted, and found to average seventy per minute. I then injected one grain of extract, mixed with a little water, into each thigh (two grains in all).

5 minutes afterwards, cardiac contractions	= 64 per min.	
10 „ „	= 58 „	
15 „ „	= 43 „	Respirations ceased, except an occasional gasp.
20 „ „	= 39 „	
25 „ „	= 41 „	No respiratory movements.
30 „ „	= 37 „	
35 „ „	= 24 „	Contractions feeble.
40 „ „	= 22 „	
45 „ „	= 22 „	Skin much darker than originally.
50 „ „	= 19 „	
55 „ „	= 13 „	
1 hour 0 min. „	= 14 „	
1 „ 5 „ „	= 12 „	Heart equally dark in systole and in diastole.
1 „ 10 „ „	= 10 „	
1 „ 15 „ „	= 9 „	
1 „ 20 „ „	= 9 „	
1 „ 30 „ „	= 10 „	
1 „ 40 „ „	= 10 „	Galvanism of sciatics caused neither direct nor reflex contractions. Muscles dark bluish, and active.
1 „ 50 „ „	= 8 „	Surface of heart opal blue in colour.
2 hours 0 „ „	= 8 „	Cardiac contractions extremely feeble.
2 „ 10 „ „	= 8 „	Skin deep olive-brown: the frog was originally a pale one.
2 „ 30 „ „	= 12 „	
3 „ 0 „ „	= 18 „	Spinal nerves still perfectly paralysed.
3 „ 30 „ „	= 21 „	
4 „ 0 „ „	= 24 „	Cardiac contractions quite synchronous, and diastole prolonged.
4 „ 30 „ „	= 26 „	A faint twitch occurred when the left sciatic was galvanised.

* *Op. cit.* section v. experiment iii.

The frog was now left in a cold and moist place until the following morning, when it was found jumping about actively, with its heart contracting forty-eight times per minute. It continued in very much the same condition for other two days, when it was killed.

This experiment is especially interesting because of the very near approach to death that was made. A decided effect was produced on the heart's action, as it was reduced in frequency by from seventy to eighty beats in the minute: respiratory movements were stopped; reflex spinal action was completely prevented; and the spinal motor nerves were, for many minutes, paralysed: and yet the animal revived; and regained all its lost functions except that of the heart, which only partially recovered itself. Such a result could never have been obtained with a warm-blooded animal, as death would soon have been produced by asphyxia, however long the heart might continue to contract. It is well known that the frog may live for many days after the removal of its lungs, as the respiratory function of those organs is shared in by the skin of this animal. The effects of the poison that was given in this case—and the dose was a very small one in proportion to the weight of the frog—had gradually disappeared, and the different tissues had returned to their former vitality, after having been acted upon for some time by a nearly normal blood-stream. Had the circulation ceased, or had the effects on the tissues been greater, and, therefore, more permanent, this return from pseudo-death could not have occurred.

Experiment XLVIII.—(*Temperature of Laboratory*, 58° *F.*)

The heart of a frog, weighing 396 grains, was exposed. After allowing a few minutes for recovery from shock, the number of the cardiac contractions was determined at intervals of five minutes, during twenty minutes, and found to vary little from forty-two beats per minute. One grain of extract, in a few drops of water, was then injected into the subcutaneous tissue of each thigh (two grains in all).

2	minutes afterwards,	cardiac contractions	= 36	per min.
4	„	„	= 24	„
6	„	„	= 20	„ — Contractions seem feeble, and heart is not so pale during systole as is normal.
8	„	„	= 17	„
10	„	„	= 17	„
12	„	„	= 15	„ — Heart walls seem nearly as dark during systole as during diastole.
14	„	„	= 14	„
16	„	„	= 14	„
18	„	„	= 15	„ — Frog is helpless and flaccid.
20	„	„	= 14	„
25	„	„	= 14	„ — Almost no difference of colour during systole, and a great prolongation of diastole.
30	„	„	= 12	„
35	„	„	= 13	„
40	„	„	= 12	„
45	„	„	= 8	„ — The ventricular contractions seem more feeble than the auricular.

50 minutes afterwards, cardiac contractions = 8 per min.

1 hour „ = 8 „ { The ventricular contraction is scarcely perceptible.

1 „ 5 min. „ are irregular; there being three ventricular contractions per minute, and six auricular.

This irregularity continued for other ten minutes, and then became greater, only one contraction per minute, of the most feeble character, occurring in the ventricles for two and sometimes three in the auricles. During the period of inaction, the heart rested in diastole.

1 hour 20 minutes after poisoning, cardiac contractions = 0 per min.

1 „ 40 „ „ „ = 8 „ { All the chambers contract, with long intervals, and in a vermicular manner.

1 „ 50 „ „ „ = 12 „

2 hours „ „ = 12 „

2 „ 10 „ „ „ = 12 „

3 „ 15 „ „ „ { Again irregular, and exactly as at one hour and five minutes after the poisoning.

3 „ 40 „ „ „ The irregularity was still further increased, the ventricles being occasionally quite motionless, in a dilated condition, for one minute, while both auricles contracted six and sometimes eight times. The contractions consisted merely of feeble wave-like movements of the different chambers. The surface of the heart, and, still more, the pericardium had for some time assumed a blue colour.

When the heart was again examined, twenty-two hours after poisoning, there was no spontaneous movement. It was then gently stimulated by an interrupted galvanic current, and a very feeble contraction of all the chambers followed, which did not repeat itself, but which could be reproduced by a renewal of the stimulation. For some time after these irritations, feeble and irregular contractions occasionally occurred, one ventricle contracting, and, after several minutes, two or three auricular movements following, but with considerable pauses. Forty-eight hours after the administration, the heart was motionless, dark and dilated; gentle galvanism produced no effect, except that the ventricles became rather paler, but a moderate current caused a contraction of all its chambers, succeeded by perfect quiet.

In sixty hours, the heart was pale and quiet, and no movement could be produced by galvanism. Notwithstanding the paleness of its walls, the heart was not contracted, as its chambers contained a considerable quantity of dark, fluid blood. The colour of its walls was, therefore, due to contraction of their capillaries, caused either by the rigor of death, or, as I am more inclined to believe, by the galvanic stimulation they had been so frequently subjected to. At this time, all the muscles were stiff.

Experiment XLIX.—(*Temperature of Laboratory*, 57° *F.*)

The average number of cardiac contractions in a frog, weighing 415 grains, was fifty-five per minute. Two grains and a-half of extract, in fifteen minims of distilled water, were injected into the subcutaneous tissue of each thigh (five grains altogether).

2 minutes afterwards, cardiac contractions = 52 per min.

4 „ „ = 50 „

6 „ „ = 24 „

8 „ „ = 19 „

10 „ „ = 15 „

12 „ „ = 14 „ No chest respiratory movements.

14 minutes afterwards, cardiac contractions = 14 per min. Systole not quite so pale as originally.

16	„	„	= 13 „	Frog is quite flaccid; it cannot turn from its back, but occasional faint struggles occur.
18	„	„	= 11 „	Contractions very feeble.
20	„	„	= 10 „	Heart as dark during contraction of the ventricles as during dilatation of them.
22	„	„	= 8 „	Irregular and non-synchronous; the auricles sometimes contracting nine or eleven times per minute.
24	„	„	= 8 „	of ventricles, 10 of auricles.
26	„	„	= 8 „	„ 14 „
28	„	„	= 7 „	„ 14 „
30	„	„	= 8 „	„ 14 „
32	„	„	= 0	during one minute, and then a few feeble contractions in the auricles, and again a pause.
34	„	„	= 0	per min.
36	„	„	= 0	„
38	„	„	= 0 „	of ventricles, 3 of auricles.
40	„	„	= 8 „	„ 12 „
42	„	„	= 8 „	„ 16 „
45	„	„	= 8 „	„ 16 „
50	„	„	= 9 „	Synchronous.
55	„	„	= 9 „	Skin extremely dark.
1 hour	0 min.	„	= 8 „	No reflex movement on stimulation.
1 „	10 „	„	= 8 „	Galvanism of the sciatic nerves causes faint twitches of the toes.
1 „	15 „	„	= 8 „	
1 „	20 „	„	= 8 „	All the spinal nerves are paralysed; the muscles remaining active and blue.
2 hours	0 „	„	= 8 „	
3 „	0 „	„	= 8 „	

The observations were now interrupted until twenty hours after the exhibition of the poison, and, at this time, the frog was quite flaccid and dark; the heart was contracting sixteen times in the minute, and the striped muscles were irritable, but otherwise the animal was quite dead. Twenty-eight hours after the exhibition of Calabar bean, the cardiac contractions were seventeen per minute; and at thirty hours they were ten. In forty hours, the heart was found perfectly still, dark and somewhat dilated. Direct galvanism produced a slow contraction of the portion of cardiac muscle included in the circuit; it did not excite a normal heart beat. The striped muscles contracted very sluggishly when galvanised. This idio-muscular contractility was retained in the heart until sixty-nine hours, and in the striped muscles till seventy hours after the administration of the poison. They then became pale, stiff and acid.

In this experiment, a large proportion of the extract had not been absorbed, but escaped from the thighs when the skin was incised to allow the sciatic nerves to be exposed. The effects cannot, therefore, be regarded as those produced by five grains, but must be held to have been caused by a much smaller quantity. Indeed, where three grains were absorbed by a frog of nearly the same weight, the action on the heart was much more decided and marked.

Experiment L.—(*Temperature of Laboratory*, 60° *F.*)

The exposed heart of a frog, weighing 469 grains, was found to contract, on an average, sixty-seven times in the minute. One grain of extract, in five minims of water, was then injected into each thigh, and a third grain was injected into the stomach by means of a narrow caoutchouc tube (total three grains).

2	minutes afterwards, cardiac contractions	=	60 per min.	
4	„ „	=	54 „	
6	„ „	=	34 „	
8	„ „	=	30 „	
10	„ „	=	21 „	Very feeble. Heart not quite so pale, now, in systole.
12	„ „	=	13 „	
14	„ „	=	11 „	Frog jumped about when set free, but soon fell on its back, and remained there.
16	„ „	=	8 „	
18	„ „	=	0 „	Colour of frog has changed from yellowish brown to dark bronze.
20	„ „	=	0 „	
22	„ „	=	0 „	of the ventricles, 2 of the auricles.
24	„ „	=	0 „	
28	„ „	=	0 „	
30	„ „	=	0 „	

After this, an occasional auricular contraction occurred, but no spontaneous movement was seen of the ventricles. The heart rested in diastole, and was of a dark colour with a bluish tinge. For twenty minutes after this, a slight stimulus excited a few rhythmical contractions, followed, in a few seconds, by rest in diastole, but capable of being reproduced in the same way. One hour and ten minutes after the administration, no reflex movement could be excited; but the sciatic nerves continued active for longer than thirty hours—the rapid stoppage of the circulation having prevented that prolonged contact with the poison that is necessary for the paralysis of the endorgans. The striped muscles remained contractile until more than forty-eight hours, and contractility was also retained by the cardiac muscle during this period.

A possible source of fallacy is introduced into these experiments by the operations that they require. It seemed, therefore, of some importance to test the effects on the frog's heart of mere exposure to the air. For this purpose, a portion of the sternum was removed from an active frog, in exactly the same manner as in the last four experiments, with the following result:—

5	minutes afterwards, cardiac contractions	=	62.
10	„ „	=	61.
20	„ „	=	62.
30	„ „	=	59.
40	„ „	=	60.
50	„ „	=	59.
1 hour	0 minutes, „	=	55.
1 „	30 „ „	=	57.
2 „	0 „ „	=	60.
2 „	30 „ „	=	56.
3 „	0 „ „	=	58.
3 „	30 „ „	=	59.
4 „	0 „ „	=	59.

It is almost needless to remark that the change in the systolic colour of the heart, from pale to dark, did not occur. The heart's surface was prevented from drying by an occasional drop of water; and this was also done during the experiments in which physostigma was administered.

We have now sufficiently described, as proposed (p. 29), "the various changes that are undergone by the heart before its contractions finally cease;" and from the data given, these may be summarised in their order of occurrence as follows:—

1st, Diminution never preceded by increase, of the frequency of the contractions, with prolongation of the period of rest; 2d, Feebleness of the contractions, with no change of colour on the occurrence of systole; 3d, Irregularity of rhythm, the auricles contracting more frequently than the ventricles, and, for intervals, contracting alone; 4th, Stoppage of all the heart's chambers—If the poison be absorbed quickly and in large quantity, the fifth and sixth effects may not occur; 5th, Renewal of contractions, either by all the chambers at once, or by one or more in the first place; 6th, Gradual recovery to a low rate of action, and continuance at this for from a few minutes to several days; 7th, Stoppage *in diastole* of spontaneous contractions; and 8th, Loss of the idio-muscular irritability of the heart, rigor and change of reaction from alkaline to acid.

This method of affecting the heart distinguishes physostigma from the great majority of cardiac poisons, which may be well represented by *Antiaris toxicaria*,* *Tanghinia venenifera*,† *Digitalis*,‡ *Helleborus niger*, *H. viridis*§ and the green resin obtained from *Nerium Oleander*.‖ These produce first irregularity and acceleration of the heart's action, then a diminished frequency, *caused by protraction of the ventricular systole*, and, finally, stoppage of the contractions by "*cessation of the dilatation of the ventricles*, which then remain contracted, white and perfectly empty."¶ In producing cardiac paralysis, physostigma acts in a manner exactly the reverse. It causes no acceleration, it diminishes the frequency of the contractions *by prolonging the ventricular diastole*, and it produces the final stoppage *by cessation of the contraction of the ventricles*, which then remain dilated, dark and full of blood. Very small doses of digitaline and the alcoholico-aqueous extract of *Nerium Oleander* are said to act on the heart in a manner which seems to resemble closely that of Calabar bean,** but no other cardiac poisons appear to share in its peculiarities.

It now remains that we examine the mechanism by which these changes are produced, and endeavour to determine what tissues or structures are influenced by physostigma to effect them. For this purpose, it will be necessary to investi-

* Kölliker, Vulpian, Claude Bernard and others, in various papers.

† M. Eug. Pélikan et Dr Dybkowski; Recherches physiologo-toxicologiques sur l'action de quelques poisons du cœur; and Comptes Rendus, 1865, p. 1209.

‡ *Ibid.* § *Ibid.* ‖ *Ibid.*

¶ On the Application of Physiological Tests for Certain Organic Poisons, and especially Digitaline, by C. Hilton Fagge, M.D., and Thomas Stevenson, M.D. Guy's Hospital Reports, 3d series, 1866, vol. xii. p. 47.

** Nouvelles Recherches sur le poison du *Nerium Oleander*. Note de M. Eug. Pélikan. Comptes Rendus, 1866, p. 237.

gate the possible influences of the cerebro-spinal nervous system, whether exerted through the vagi or through the spinal nerves, and the possible influences of the sympathetic system, whether exerted through the great sympathetic trunks and their branches or through the ganglia contained in the heart's substance. Any effect on idio-muscular contractility has been already abundantly disproved; but it will be necessary to observe how far the impairment and cessation of respiration may explain the cardiac effects in warm-blooded animals.

The paralysis of the heart in diastole and the diminution in the frequency of its contractions by protracted periods of rest in a *dilated condition*, as well as the frequent renewal of its action after a long pause in diastole, might, in the first place, suggest that the inhibitory function of the vagi nerves was being exerted. On this account, it may be advisable to examine their condition during Calabar bean poisoning.

Experiment LI.

An active frog was selected, of the weight of 863 grains, and its heart and two vagi nerves were exposed. The latter were separately tested by galvanism, and each produced stoppage of the heart's action, in diastole. A few minutes afterwards, the average of the heart's contractions was ascertained to be fifty-eight in the minute. Three grains of extract, in a few drops of water, were injected into the subcutaneous tissue of the two thighs—one-half into each.

2 minutes afterwards,	cardiac contractions = 54 per min.		
4 „	„ = 47 „		
6 „	„ = 40 „		
8 „	„ = 37 „		
10 „	„ = 36 „		
12 „	galvanism of the left vagus produced stoppage in diastole.		
14 „	cardiac contractions = 34 per min.		
16 „	„ = 33 „	Contractions feeble.	
18 „	„ = 30 „	Heart dark in systole, as well as in diastole.	
20 „	„ = 24 „		
25 „	„ = 20 „		
30 „	„ = 19 „		
35 „	galvanism of the left vagus produced stoppage for one minute.		
40 „	cardiac contractions = 15 per min.		
45 „	„ = 18 „		
50 „	„ = 14 „	Marked pause between auricular and ventricular contractions.	
1 hour 0 min.	„ = 12 „		
1 „ 5 „	galvanism of the left vagus produced stoppage of all the chambers.		
1 „ 10 „	cardiac contractions were irregular, on being renewed; only twelve ventricular now occurring to eighteen auricular, per minute.		
1 „ 20 „	cardiac contractions continue, with the above irregularity.		
1 „ 30 „	cardiac contractions still irregular; galvanism of the left vagus produced stoppage of all the chambers, but a stronger current was required than before.		
1 „ 32 „	galvanism of either sciatic nerve caused movements confined to the limb whose nerve was stimulated.		
1 „ 40 „	cardiac contractions continue irregular, as above.		

1 hour 50 min. afterwards,	galvanism of the left vagus produced stoppage of all the chambers; and the heart remained at rest, in diastole, for ten minutes, when a feeble auricular contraction occurred, and, soon after, a ventricular.
1 „ 55 „	galvanism of either sciatic nerve caused merely faint twitches of the toes.
2 „ 10 „	cardiac contractions = 18 per minute; very feeble, but rhythmical.
2 „ 15 „	strong and continued galvanism of the left vagus produced no effect on the cardiac contractions.
2 „ 18 „	strong and continued galvanism of the right vagus, which had not been irritated during the experiment, produced no effect on the cardiac contractions.
2 „ 20 „	strong galvanism applied to either sciatic nerve produced no effect.
2 „ 40 „	cardiac contractions stopped. Irritation could produce a few contractions for only a few minutes longer.

From this experiment it is apparent that the vagi retain their inhibitory power over the heart during the whole period that its action is being modified by physostigma. Ultimately, however, they are themselves paralysed, as might be anticipated from the analogies that exist between them and the spinal nerves; and, as this and many other similar experiments prove, the functions of the vagi and of the spinal motor nerves are lost simultaneously, or nearly so.

To illustrate this in warm-blooded animals, it is necessary to exhibit so small a dose of the poison that death shall be caused by asphyxia, and the heart afterwards continue to contract, however irregularly.

Experiment LII.

Half a grain of extract, suspended in ten minims of distilled water, was injected under the skin on the back of a full-grown and active rabbit. The usual symptoms followed; and, in thirty-four minutes, the animal was dead, all respiratory movement having ceased. Immediately afterwards, the heart was exposed; and it was found contracting in normal rhythm, twenty-two times in the minute. The right vagus was divided; and the end proximal to the heart was galvanised, with the effect of producing an immediate stoppage, in diastole, for several seconds. The vagi were tested, occasionally, during twenty minutes after the rabbit's death, and their cardiac inhibitory function, as well as their excito-motory power over the stomach and œsophagus, continued active all this time; and, for the same period, the sciatic, intercostal, phrenic and other spinal nerves retained their motor conductivity. Twenty-two minutes after death, the heart was contracting eight times per minute. Galvanism of either vagus could now neither stop the cardiac action nor excite œsophageal or gastric movements. The sciatic and other spinal nerves were tested at twenty-five minutes after death, and found to be perfectly paralysed.

It is, therefore, quite possible, as far, at least, as conveyance by the vagi nerves is concerned, for Calabar bean to act on the heart by exciting the cardiac inhibitory centre in the medulla oblongata. But, if this be the method of its action, the prevention of this possible influence, by division or previous paralysis of the vagi, or by destruction of the medulla oblongata, should render it impossible for Calabar bean to produce its usual effects on the heart.

Experiment LIII.

The heart and the two vagi nerves were exposed and the latter divided in a frog, weighing 700 grains, and, a few minutes later, the cardiac contractions were found to have an average of sixty-six in the minute. Two grains of extract, in ten minims of distilled water, were then injected into each thigh (altogether four grains).

2 minutes afterwards, cardiac contractions		= 60	per min.	
4	„	= 60	„	
6	„	= 53	„	
8	„	= 46	„	
10	„	= 39	„	
12	„	= 31	„	
14	„	= 27	„	
16	„	= 24	„	
18	„	= 22	„	
20	„	= 18	„	
22	„	= 16	„	All the chambers are of dark colour, even in systole.
24	„	= 13	„	
26	„	= 14	„	
28	„	= 12	„	Ventricular contraction is extremely feeble.
30	„	= 10	„	
35	„	= 9	„	
40	„	irregular; six ventricular for twelve auricular.		
42	„	stopped in diastole, for thirty-five seconds.		

The heart then resumed its previous unrhythmical action of six ventricular to twelve auricular movements in the minute, and continued to contract, with various changes of irregularity, for many hours longer.

It would needlessly occupy space, were I to narrate any other of the many experiments that were performed with frogs whose vagi had been divided; as the results, and even the details, were in all of them very much the same. It might be proper to instance, at this place, an experiment of the same character on a warm-blooded animal, but I content myself by referring to Experiment LXI., at page 49.

In curare we possess an agent that, within a few minutes after its exhibition, produces complete paralysis of all the motor nerves, including the vagi.* It will, therefore, act as effectually as division, in preventing any inhibitory influence being exerted on the heart.

Experiment LIV.

A small dose of curare was inserted under the skin of a frog's back. Ten minutes afterwards, the animal was perfectly paralysed. At twenty minutes, its heart was exposed, and observed to be contracting fifty-four times in the minute. The vagi and sciatic nerves were tested by galvanism, and their conductivity was found to be completely destroyed. Three grains of extract of physostigma, in water, were injected into the two thighs. The usual cardiac effects were produced within the time that might have been expected, from such a dose; irregularity of the rhythm having occurred in forty-four minutes, and final paralysis, with all the chambers dark, full and dilated, in a few minutes later.

* Claude Bernard, Leçons sur les effects des Subs. Tox. &c., p 352; Köllikeb, *loc. cit.*; Martin-Magron, Journal de la Physiologie, 1859, p. 649, &c.

These are sufficient to prove that Calabar bean influences the heart neither by an action on the inhibitory centres nor by one on the nerves that connect those centres with it. I think they are also sufficient to exclude the rest of the cerebro-spinal nervous system: as the only other spinal nerves connected with the heart, by the branches of the great sympathetic trunks or otherwise, are either sensory, or at any rate afferent, nerves that form through the cord reflex arrangements with the vagi and vaso-motor nerves; or excito-motory ones whose action is to increase the frequency of the heart's contractions, but whose function is only periodically exerted, and is quite unnecessary for the continuance of the ordinary rhythmical occurrence of those contractions.* But, to remove the possibility of any doubt on this point, the following experiment was performed:—

Experiment LV.

The spinal cord was divided between the occiput and first vertebra of a frog, weighing 376 grains, and a wire was passed down the spinal canal, so as to produce complete paralysis, and into the cranial cavity, so as thoroughly to break up and destroy the brain. A short time thereafter, the heart was contracting at the rate of forty beats per minute. One half of three grains of extract, in twenty minims of water, was injected into each thigh.

2	minutes afterwards,	cardiac contractions	= 37	per min.
4	„	„	= 31	„
6	„	„	= 28	„
8	„	„	= 26	„
10	„	„	= 25	„
12	„	„	= 24	„
14	„	„	= 22	„
16	„	„	= 20	„
18	„	„	= 17	„
20	„	„	= 14	„
22	„	„	= 13	„
24	„	„	= 12	„

* Dr Power observes, in the sixth edition of Carpenter's "Principles of Human Physiology" (page 217, note), that "the essential cause of the rhythmical action of the heart must still remain an unsolved question." The exact influence of the various nerves that connect the heart with the central nervous systems, appears to be quite as imperfectly ascertained, judging by the contradictory statements and deductions of eminent physiologists. Legallois and Philip Wilson, and, afterwards, Budge, Schiff, Reid, Weber, Moleschott, Von Bezold and others, have shown that a connection certainly exists; but they have left the details of the question unsettled by the great differences in many of their opinions, as, for example, on the cardiac functions of the vagi. Von Bezold, in 1863, attempted to prove the existence, in the spinal cord, of an excito-motory centre, whose stimulation increases not only the number of the beats, but also the blood-pressure—the latter being due to augmented force in the heart's contractions. Ludwig and Thiry opposed this opinion, and asserted that the increased blood-tension is really an effect of excitation of the vaso-motor nerves. In a recent investigation (Comptes Rendus, 25 Mars 1867), MM. E. and M. Cyon give their adherence to the views of Ludwig and Thiry. They also attempt to show that the spinal cord, through the sympathetic system, supplies the heart with nerves that possess the power of directly accelerating its contractions, and that are antagonistic to the vagi, in that, while the latter diminish the frequency and increase the force of the contractions, the spinal "nerfs accélérateurs," on the other hand increase the frequency and diminish the force.—*April* 1867.

26 minutes afterwards, cardiac contractions = 9 per min.

28 „ „ = 9 „ { Very feeble. Heart dark during systole.

30 „ „ = 7 „

35 „ „ irregular; four ventricular for six auricular.

Irregular and unrhythmical contractions continued for many hours afterwards. The final stoppage was in diastole.

It may now be useful to examine what connection exists, as cause and effect, between the impairment and cessation of the respiratory movements and the interference with, and stoppage of, the cardiac contractions, especially as so deservedly distinguished a physiologist as HARLEY has asserted that Calabar bean is a respiratory poison purely, which causes death by destroying the conductivity of the motor nerves of respiration. CHRISTISON, in his investigation, was the first to observe an action on the heart, and he believes that death is caused by paralysis of that organ. My former results were, so far, in accordance with this statement; but they also show that death may often be due to asphyxia, and while I agree with HARLEY in this, I believe him to be in error when he asserts that paralysis of the motor nerves is the cause of such death. The data that have already been given are sufficient to prove that motor nerve conductivity is always retained, in warm-blooded animals as well as in cold, for many minutes after the complete stoppage of respiratory movements, and that such stoppage is due to destruction of the reflex and co-ordinating functions of the medullæ spinalis and oblongata. To complete this evidence, it will be sufficient to show that no connection of cause and effect necessarily exists between the impaired respiratory movements and the cardiac paralysis.

Experiment LVI.

In a large retriever dog, it was found that the mean number of respirations was ten, and the mean number of cardiac contractions 126, during seven minutes immediately preceding the injection of six grains of extract, suspended in water, into the right jugular vein.

1 min.		after the injection, the respirations	=	10,	cardiac contractions	=	78	per min.
1 „	30 sec.	„	„	= 11,	„	=	54	„
2 „	2 „	„	„	= 9,	„	=	40	„
3 „	0 „	„	„	= 9,	„	=	8	„
7 „	0 „	„	„	= 10,	„	=	20	„
9 „	0 „	„	„	= 10,	„	=	16	„
10 „	0 „	„	„	= 9,	„	=	9	„
10 „	30 „	„	„	= 0,	„	=	0	„

This experiment gives the result that, in one minute and thirty seconds after the poison was administered, the number of cardiac contractions had fallen to less than one-half, while the respiratory movements had increased by one per minute; and it distinctly shows the absence of any respiratory change to cause the marked effects that were produced on the heart's action.

Experiment LVII.

A frog, weighing 460 grains, had its heart exposed by removing a small portion of the sternum. It was acting at the rate of forty-eight beats per minute, while the respirations were seventy-two. Five minutes afterwards, the heart was contracting at the rate of forty-five per minute, while the respirations were seventy-four. One grain and a half of extract, suspended in water, was injected under the skin of each thigh (three grains in all).

In	5 min., heart = 36 per min.		Respirations = 74 per min.
	10 „ „ = 28 „		„ = 64 „
	15 „ „ = 22 „		„ = 63 „
	20 „ „ = 14 „	Contractions weak; and heart continues dark during systole.	„ = Frequent gasping movements, which cannot be counted.
	25 „ „ = 13 „		„ =
	30 „ „ = 12 „		„ An occasional gasp.
	40 „ „ = 10 „		„ have stopped.
	50 „ „ = 10 „		
1 h.	0 „ „ = 8 „	Contractions very feeble.	
1 „	10 „ „ = 8 „		
1 „	15 „ „ = 0 „	Stopped in diastole.	
1 „	20 „ „ = 0 „		
1 „	30 „ „ = 12 „		
1 „	40 „ „ = 12 „		
1 „	50 „ „ = 12 „		
2 „	0 „ „ = 10 „		
2 „	30 „ „ = 8 „	Contractions irregular; two auricular for one ventricular.	

These two experiments prove distinctly that Calabar bean has a direct influence on the heart, that is quite independent of the indirect influence it exerts on that organ by arresting the respiratory movements. Such arrest does, doubtless, assist the action on the heart, especially during the later stages of the poisoning, by impeding the circulation; and in mammals, when a small dose has been exhibited, such comparatively slight diminution as is first produced in the frequency of the heart's contractions must even be partly caused by the early retardation and cessation of the respiratory movements that constantly occur.

The cardiac action of physostigma is, thus, quite independent of the cerebro-spinal nervous system, and is not a mere effect of the paralysis of respiration. It must, therefore, be caused by an action of a direct nature on the cardiac ganglia. which seem to be the only constant exciters of this organ, however its contractions may be *regulated* by other nerves. The peculiar changes that the heart's action undergoes—the diminution in the frequency of its beats, then their stoppage or irregularity, sometimes followed by renewal of rhythmical contractions, or of independent movements in all the chambers, or in one only—prove that Calabar bean first diminishes the vitality of the exciting ganglia, and then paralyses them. Their influence is, at any rate, maintained until spontaneous movements cease; for, if we divide the ventricles from the auricles at a late stage of the poisoning and when the contractions are unrhythmical, those chambers alone

that are still in connection with the great exciter ganglia in the auriculo-ventricular septum will continue their spontaneous movements.

The action is not a very powerful one, and its characteristics may be explained because of that; for the effects of physostigma on the heart appear to be similar to those of *weak forms* of at least two of the ordinary cardiac poisons—of digitaline in minute doses, and of the alcoholico-aqueous extract of *Nerium Oleander*, which is merely the green extract mixed with various impurities, without which it has the ordinary actions of the larger class of those substances that affect the heart.*

ACTION ON THE BLOOD-VESSELS.

The question of the action of Calabar bean on the condition of the vascular system is intimately connected with that of the cardiac effects; and must, therefore, be considered also, that we may complete the examination of the influence of this substance on the circulation. For this purpose, I instituted two sets of experiments. In the first (1), the blood-tension in the arterial and venous systems was observed; and in the second (2), the calibre-changes of the smaller blood-vessels and of the capillaries were investigated.

1. *Examination of the Blood-Tension, and of the Coincident Changes in the Cardiac and Respiratory Movements, and in the Temperature.*

In these experiments, the tension in the arterial system was determined by dividing one of the carotid arteries and connecting the end proximal to the heart with a modification of POISSEUILLE'S hæmadynamometer, in which two indicating columns were connected with the reservoir. The tube of one of these had an extremely small orifice where it dipped into the mercury, and it, therefore, registered the mean pressure only. The orifice of the other had the same diameter as the rest of the tube, and the contained mercury had, therefore, immediately communicated to it every change of pressure, and oscillated synchronously with the heart's beats. The venous pressure was ascertained by a simple hæmadynamometer having one registering column. The indicating columns were divided into inches and tenths of inches.

In the experiments where the temperature was observed, a delicate thermometer was inserted into the subcutaneous tissue at the flank of the animal, and retained there, under the charge of an assistant, during all the time of the experiment.

* PÉLIKAN, *op. cit.*, Comptes Rendus, 1866.

a. *Arterial Tension only.*

Experiment LVIII.

A large and vigorous retriever dog was placed on a table, and tied down by its four limbs.*

Time.	Time after Administration.	Mean Pressure.	Pressure Oscillates between	No. of Cardiac Contractions.	No. of Respirations.	Notes of Operations and of Symptoms.
H. M. S.	M. S.			Per Min.	P r Min.	
3 16 0 P.M.	...	...	...	...	20	The right carotid artery was exposed and connected with the hæmadynamometer.
3 16 30	...	6·8	5·2 & 9·0	...	...	
3 19 0	...	7·0	5·0 9·0	86	18	
3 20 30	...	6·9	5·3 9·3	...	18	
3 22 0	...	7·2	5·3 9·3	108	19	
3 24 0	...	7·0	5·1 8·9	...	...	
3 26 20	...	...	...	...	...	Two grains of extract, in forty minims of distilled water, were injected into the subcutaneous tissue of the abdomen.
3 26 30	...	6·8	5·5 9·0	102	...	
3 26 50	...	...	...	...	...	The injection of the poison was completed.
3 29 0	2 10	6·9	4·9 9·2	93	19	Dog is perfectly quiet.
3 33 0	6 10	6·8	4·5 9·2	90	18	A few struggles occurred.
3 35 0	8 10	6·7	4·9 8·5	75	17	
3 38 30	11 40	7·5	5·0 10·0	90	19	Somewhat violent struggles.
3 41 0	14 10	7·8	5·5 9·3	90	15	Muscular twitches over nearly all the body.
3 41 30	14 40	8·0	...	...	17	
3 42 0	15 10	8·4	7·0 10·0	...	21	Muscular twitches have increased in violence.
3 43 0	16 10	8·9	7·0 10·0	...	22	
3 44 0	17 10	8·8	7·5 10·4	...	...	
3 45 0	18 10	8·5	7·0 9·3	106	...	
3 46 0	19 10	8·3	7·0 9·3	104	31	
3 48 0	21 10	8·2	6·5 9·5	98	38	Twitches are now much feebler; great lachrymation and salivation.
3 50 0	23 10	8·15	7·5 9·5	...	9	
3 52 0	25 10	7·9	6·5 9·4	96	40	
3 55 0	28 10	7·65	6·5 9·9	96	37	
3 57 0	30 10	7·55	6·5 8·6	...	30	Urine and fæces passed.
3 58 0	31 10	...	...	...	34	Respirations noisy, from mucus in the trachea.
3 59 0	32 10	7·3	6·0 8·5	100	28	Very fluid fæces passed.
4 0 0	33 10	7·2	6·3 8·5	112	25	
4 3 30	36 40	7·1	6·0 8·0	112	22	The twitches have very much diminished in force.

* I have much pleasure in acknowledging the valuable assistance I derived in this series of experiments from my friend, Dr GAMGEE. I am also indebted, for essential aid in all or several of them, to Dr BRUNTON, and to Messrs PATON, RITCHIE, FINLAY, CATON, HOGG, HOLDEN, WRIGHT, HARDIE, GAIRDNER, GLASCOTT, LUCAS, M'EWAN, HOWIESON, CROMBIE and YOUNG. Without the co-operation of these gentlemen, it would have been quite impossible to obtain the many simultaneous observations which are contained in these experiments, and to which much of their value is due.

Experiment LVIII.—continued.

Time.	Time after Administration.	Mean Pressure.	Pressure Oscillates between	No. of Cardiac Contractions.	No. of Respirations.	Notes of Operations and of Symptoms.
H. M. S.	M. S.			Per Min.	Per Min.	
4 6 0 P.M.	39 10	7·0	...	...	24	
4 7 0	40 10	6·9	6·0 & 7·8	116	23	
4 10 0	43 10	6·8	5·8 7·5	120	22	The twitches are now few, faint and occasional.
4 16 0	49 10	6·8	5·6 7·3	128	23	
4 17 30	50 40	6·7	5·8 7·3	...	22	The dog appears almost perfectly well.
4 19 0	...	6·9	5·5 7·5	124	...	It was deemed advisable to administer a second dose at this stage.
4 22 0	...	...	...	...	...	Commenced the injection of four grains of extract, in thirty minims of distilled water, into the subcutaneous tissue of the right flank.
	Time after Second Administration.					
4 22 30	...	...	...	122	21	The injection was completed.
4 23 0	0 30	6·8	5·8 7·5	....	22	
4 24 0	1 30	6·7	6·0 7·5	...	23	
4 27 0	4 30	7·0	5·8 7·5	120	22	Strong muscular twitches have reappeared.
4 28 0	5 30	6·75	6·0 8·0	116	21	Liquid fæces passed, and urine "jetted" out in a full and abundant stream
4 30 0	7 30	7·0	...	...	21	
4 30 30	8 0	7·35	...	...	...	
4 31 0	8 30	6·9	6·3 8·3	120	...	Respirations are rather laboured.
4 33 0	10 30	6·9	6·0 8·0	...	22	
4 34 0	11 30	7·1	6·0 8·0	118	...	
4 35 0	12 30	7·2	6·3 8·0	...	...	
4 37 0	14 30	7·4	6·0 8·0	...	23	
4 38 0	15 30	7·3	6·5 8·3	116	22	
4 42 0	19 30	7·6	6·0 8·3	120	24	Twitches are so strong as to cause frequent slight spasms.
4 44 0	21 30	7·15	6·4 7·8	112	25	
4 46 30	24 0	7·2	6·5 8·5	...	...	Urine and fæces discharged copiously.
4 47 0	24 30	7·5	6·5 9·5	...	23	
4 48 0	25 30	7·8	6·0 11·0	92	26	
4 49 30	27 0	7·3	5·6 10·0	30	...	
4 50 0	27 30	7·1	...	...	...	
4 50 15	27 45	6·9	...	...	...	
4 50 30	28 0	6·7	5·0 8·5	...	23	
4 50 31	28 1	6·2	...	...	...	
4 50 35	28 5	5·9	...	...	...	
4 50 38	28 8	5·8	...	...	...	
4 50 40	28 10	5·4	4·0 7·0	40	...	
4 51 0	28 30	5·4	4·0 4·7	...	...	The twitches continue with considerable strength.
4 51 30	29 0	6·9	...	...	25	

Experiment LVIII.—continued.

Time.	Time after Second Administration.	Mean Pressure.	Pressure Oscillates between	No. of Cardiac Contractions.	No. of Respirations.	Notes of Operations and of Symptoms.
H. M. S.	M. S.			Per Min.	Per Min.	
4 52 0	29 30	7·2	6·0 & 9·0	...	...	
4 53 0	30 30	7·1	5·9 9·0	...	...	
4 54 0	31 30	6·3	5·9 8·2	...	...	
4 55 0	32 30	6·3	5·0 8·0	24	...	
4 55 20	32 50	5·6	4·0 8·0	...	...	
4 55 30	33 0	6·1	5·0 8·0	...	...	
4 56 0	33 30	5·0	4·5 7·0	...	21	
4 57 0	34 30	4·6	3·5 5·8	22	...	
4 57 15	34 45	4·0	3·5 5·5	...	...	
4 57 30	35 0	4·4	3·5 6·0	...	...	
4 58 0	35 30	4·4	3·0 6·0	...	27	The respirations are extremely shallow and gasping.
4 59 0	36 30	4·0	3·0 5·0	...	...	
4 59 30	37 0	3·5	2·5 4·5	...	...	
5 0 0	37 30	2·5	1·0 3·0	...	...	
5 0 30	38 0	1·8	1·0 2·5	18	4	Respirations are mere gasps.
5 1 15	38 45	1·6	1·0 2·0	...	4	
5 1 30	39 0		1·0 1 5	...	...	Mercurial column has fallen into the reservoir.

In the autopsy, which was immediately made, the heart was found dilated with dark blood. Occasional contractions occurred for twenty minutes after death. The sciatic, intercostal and phrenic nerves were active, and galvanism of a vagus nerve excited vermicular movements of the stomach. The intestinal peristalsis was feeble. Galvanism of the cervical sympathetics produced no contraction of the pupils. A quivering movement continued in the striped muscles for many minutes.

The first portion of this experiment shows that after the administration of the poison a very distinct rise occurs in the arterial tension, while the number of the cardiac contractions rapidly diminishes during this rise, and before the frequency of the respirations has been affected. The second, and larger, dose did not influence the arterial tension so powerfully, nor did it exert so immediate an action on the frequency of the heart's beats. Both doses were administered in such a manner that their absorption was comparatively slow; in the following experiments, physostigma was directly injected into the circulation, and its action was, therefore, more rapidly and energetically produced.

b. *Tension of the Arterial and Venous Systems.*

Experiment LIX.

Performed on a large retriever dog, vigorous and in perfect condition.

Time.	Time after Administration.	Arterial Tension.		Venous Tension.	No. of Cardiac Contractions.	No. of Respirations.	Temperature.	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
2 58 0	...	...	...	...	...	...	...	The right carotid artery was exposed, and attached to the hæmadynamometer.
3 1 0	...	...	...	...	...	...	...	The left jugular vein was attached to the second hæmadynamometer.
3 2 0	...	5·8	4·3 & 7·0	...	...	...	...	
3 3 0	...	6·0	5·0 7·0	2·8	...	...	...	
3 4 0	...	6·0	4·5 7·5	2·4	...	...	...	
3 5 0	...	6·0	4·6 7·0	2·2	...	...	...	
3 6 0	...	6·2	5·0 8·0	2·2	...	...	...	
3 7 0	...	7·0	5·0 8·0	1·9	...	...	...	
3 8 0	...	6·1	4·0 7·0	1·7	...	...	...	
3 8 30	...	5·5	5·0 7·0	....	...	...	...	
3 9 0	...	6·3	3·3 7·0	1·7	120	...	...	
3 10 0	...	5·9	3·0 6·7	...	...	8	99·2	
3 12 0	...	5·4	4·0 6·5	1·8	...	...	99·8	The dog seems perfectly calm.
3 13 0	...	5·9	4·0 7·0	...	126	10	...	
3 14 0	...	5·6	4·5 6·5	...	132	...	100·0	
3 15 0	...	5·6	4·5 7·0	...	...	10	...	
3 15 30	...	5·5	5·0 7·0	...	...	...	...	
3 16 0	...	6·6	5·0 7·0	1·8	...	12	99·9	
3 16 15	...	...	...	...	...	...	...	Commenced the injection of six grains of extract, in twenty minims of water, into the right jugular vein.
3 16 30	...	...	...	...	...	...	...	The injection was finished.
3 17 0	0 30	6·0	4·0 7·0	2·8	120	...	...	
3 17 30	1 0	4·3	...	...	...	...	...	The muscles are twitching; fæces passed.
3 17 35	1 5	4·9	...	...	...	...	...	
3 17 45	1 15	6·5	4·0 11·0	...	...	...	...	
3 17 50	1 20	7·0	5·0 11·5	...	...	...	...	
3 18 0	1 30	8·4	5·2 11·9	3·4	78	10	99·9	Urine passed; saliva is escaping from the mouth in large quantity.
3 18 30	2 0	8·5	5·5 12·0	...	...	...	...	
3 19 0	2 30	7·9	5·0 10·0	3·4	...	...	...	The twitches are now severe, and have a spasmodic character.
3 19 15	2 45	7·3	5·0 9·0	...	54	11	100·2	
3 19 30	3 0	6·5	4·5 8·0	3·4	...	...	...	No movement of the eyelids when the cornea or conjunctiva is touched.
3 20 0	3 30	5·1	4·0 8·0	3·4	40	...	100·4	The muscular twitches have become less marked.

Experiment LIX.—continued.

Time.	Time after Administration.	Arterial Tension.		Venous Tension.	No. of Cardiac Contractions.	No. of Respirations.	Temperature	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
3 20 15	3 45	5·0	...	...	...	...	...	Excessive lachrymation.
3 20 30	4 0	4·7	2·5 & 6·0	3·2	...	...	...	
3 20 40	4 10	3·7	3·0 6·0	...	...	...	...	
3 20 50	4 20	3·8	3·0 6·5	3·0	...	...	100·4	
3 21 0	4 30	4·3	3·0 6·0	2·9	32	...	...	Cardiac impulse quite perceptible to the touch.
3 21 15	4 45	3·5	2·0 5·0	...	...	...	100·4	The dog is now quite quiet.
3 21 30	5 0	3·0	2·0 5·0	2·8	...	...	...	Third eyelid is protruded slightly, and the eyeball is directed downwards and inwards.
3 22 0	5 30	2·6	2·0 5·5	2·4	24	8	100·3	
3 22 15	5 45	3·1	3·0 5·0	2·2	...	...	...	
3 22 30	6 0	2·5	2·0 5·0	2·1	...	...	...	Cardiac impulse can still be felt readily.
3 23 0	6 30	2·6	2·0 4·5	2·0	22	...	100 3	
3 23 30	7 0	2·7	1·5 5·0	1·9	...	...	...	Respirations are short and jerking.
3 24 0	7 30	2·5	2·0 3·5	1·8	20	10	100·3	
3 25 0	8 30	2 6	2·0 3·5	1 9	12	...	100·3	An occasional faint muscular twitch occurs.
3 26 0	9 30	2·7	2·3 3·0	1·7	16	10	100·2	Respirations are gasps merely.
3 26 15	9 45	2·5	2·0 3·5	...	...	...	...	
3 26 30	10 0	2·4	2·0 3·0	...	...	6	...	No reflex movement on severe irritation.
3 27 0	10 30	2·2	2·3 2·5	1·7	14	...	100 2	
3 27 30	11 0	1·3	2·0	1·6	...	...	100·2	
3 27 40	11 10	...	...	1·0	...	...	...	Cardiac and respiratory movements have ceased.
3 28 0	11 30	...	...	...	...	...	100·1	
3 33 0	16 30	...	...	...	...	...	100·0	
3 35 0	18 30	...	...	...	...	...	99·7	

The exposed heart was found, in the autopsy, to be perfectly quiet; and only one or two irregular non-synchronous movements could be obtained when it was stimulated. All its chambers were full of blood. Slight peristaltic movements were observed in the small intestines.

Experiment LX.

Experiment LX.

Performed on a large and very active Newfoundland-and-retriever cross-bred dog.

Time.	Time after Administration.	Arterial Tension.		Venous Tension.	No. of Cardiac Contractions.	No. of Respirations.	Temperature.	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
2 53 0	...	...	...	...	...	...	...	The arterial hæmadynamometer was connected with the right carotid artery.
2 54 0	...	...	...	...	...	...	...	The left jugular vein was attached to the venous hæmadynamometer.
2 56 0	...	6·0	4·5 & 7·0	...	118	34	98·0	
2 57 0	...	5·8	4·0 7·0	2·4	...	...	...	
2 58 0	...	6·2	5·0 7·5	2·4	...	28	100·1	
3 0 0	...	6·0	5·0 8·0	2·5	...	...	...	
3 3 0	...	6·0	5·0 8·0	2·5	...	...	99·9	
3 4 0	...	6·0	5·0 6·5	...	176	30	...	
3 5 0	...	6·1	4·8 7·0	...	...	...	100·2	
3 6 0	...	6·1	5·0 6·5	...	180	26	...	
3 7 0	...	6·3	6·0 7·0	3·0	...	...	...	
3 8 0	...	6·1	5·0 7·2	3·5	175	...	...	
3 9 0	...	6·0	4·5 7·0	...	...	...	100·1	
3 10 0	...	6·1	5·0 7·0	2·9	160	...	...	
3 10 30	...	...	...	...	...	...	...	Commenced the injection, into the right jugular vein, of seven grains of extract, in twenty-five minims of distilled water.
3 10 40	...	...	...	...	...	...	...	The injection was finished.
3 11 30	0 50	6·0	4·7 7·0	...	...	...	...	
3 12 0	1 10	5·9	4·5 6·5	3·1	108	...	...	Marked twitches occurred.
3 12 30	1 40	6·0	4·5 6·5	3·2	...	...	100·3	
3 13 0	2 50	...	5·0 6·0	3·3	...	25	...	
3 14 0	3 20	5·9	6·0 7·0	3·2	...	...	100·3	
3 14 30	3 50	...	...	3·4	...	...	...	
3 15 0	4 20	5·8	...	4·2	...	22	100·4	
3 16 0	5 20	7·0	5·5 8·0	4·3	42	25	...	Respirations are feeble and short.
3 16 30	5 40	6·5	5·0 8·5	3·8	...	...	100·3	
3 17 0	6 20	6·8	5·5 7·5	3·2	32	...	...	Twitching interferes with, and prevents the counting of, the respirations.
3 18 0	7 20	7·6	6·7 8·9	3·5	32	...	100·5	
3 18 30	7 50	5·0	4·0 5·0	4·2	...	...	...	
3 18 45	8 5	...	...	4·0	...	...	...	
3 19 0	8 20	4·5	3·0 4·0	3·8	24	...	100·5	
3 19 30	8 50	4·0	3·0 4·5	...	...	...	...	Occasional gasps.
3 19 45	9 5	3·1	2·5 3·5	...	...	...	100·3	
3 20 0	9 20	2·6	2·0 2·8	3·5	20	10	...	
3 20 30	9 50	2·4	2·0 2·7	3·2	...	...	100·2	
3 21 0	10 20	2·3	2·0 2·5	2·9	16	13	100·2	
3 21 30	10 50	2·4	2·0 2·4	2·7	...	10	...	Muscles are now *quivering*, not twitching.

Experiment LX.—continued.

Time.	Time after Administration.	Arterial Tension.		Venous Tension.	No. of Cardiac Contractions.	No. of Respirations.	Temperature.	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
3 22 0	11 20	1·9	1·5 & 2·3	2·7	8	...	100·1	
3 22 30	11 50	...	...	2·4	6	...	...	No respiratory movements, except an occasional jerking inspiration.
3 23 0	12 20	2·0	2·0 2·1	2·3	...	...	...	
3 23 30	12 50	1·8	1·5 1·7	2·1	...	...	...	
3 24 0	13 20	1·5	1·5 1·6	2·0	...	...	...	
3 24 15	13 35	...	...	1·9	...	...	...	
3 24 30	13 50	1·5	0·6 1·0	1·0	...	...	...	
3 24 45	14 5	0	0	0	0	0	...	The three indicating columns of mercury have subsided into their reservoirs.
3 25 0	14 20	...	...	...	...	...	100·0	
3 26 0	15 20	...	...	...	...	...	99·0	
3 27 0	16 20	...	...	...	...	...	99·3	

The abdomen and chest were immediately opened: the heart was dilated, full and motionless; and no peristalsis could be observed in the intestines. The diastaltic function of the cord was completely abolished, while motor nerve-conductivity was retained, for at least five minutes after death, in the sciatic, phrenic and intercostal nerves.

The principal results of these experiments are indicated so clearly that it is almost superfluous to point them out. During the first stage, the arterial tension diminishes slightly, the venous tension increases and the cardiac contractions rapidly diminish. The frequency of the respirations was increased in only the first experiment. After this, the arterial tension increases, soon arrives at a maximum considerably above its average before the poisoning, and then slowly diminishes; while the venous tension arrives at a high maximum rather later, and by more gradual stages, than the arterial, and in the same gradual manner declines until death. In neither system is the highest point reached before a very considerable fall has been caused in the frequency of the heart's contractions. The temperature rises during the poisoning, and attains its maximum near the time that the blood-pressures have commenced finally to diminish.

As these marked changes in the circulation could be produced before the respiratory function was modified to any important extent, it did not seem to me at all necessary to repeat the experiments with the addition of artificial respiration.

It is interesting to observe the same phenomena produced by physostigma after the division of the vagi nerves.

c. *Tension of the Arterial and Venous Systems after Division of the Vagi Nerves.*

Experiment LXI.

Performed on a young, full-grown and active retriever dog.

Time.	Time after administration.	Arterial Tension.		Venous Tension.	No of Cardiac Contractions.	No. of Respirations.	Temperature.	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
2 38 0	...	...	...	...	...	...	...	The carotid artery, external jugular vein and vagus nerve of each side were exposed.
2 48 0	...	...	...	...	...	...	...	The venous hæmadynamometer was attached to the left jugular vein.
2 49 0	...	...	...	1·9	118	...	99·8	
2 50 0	...	...	...	1·8	...	...	99·2	The right carotid artery was connected with the second hæmadynamometer.
2 51 0	...	...	...	2 0	...	18	98·8	
2 52 0	...	4·9	4·0 & 6·0	...	102	...	98·7	
2 53 0	...	4·7	3·5 5·5	1·5	...	20	99·2	
2 54 0	...	5·0	4·0 6·0	2·2	108	...	99·0	
2 55 0	...	4·2	3·5 5·0	...	...	...	99·3	
2 56 0	...	...	...	...	80	...	99·2	
2 57 0	...	...	...	...	92	...	99·2	
2 58 0	...	4·5	3 0 5·5	2·1	...	...	...	
2 59 0	...	4·4	3·0 5·0	2·1	...	..	...	
3 0 0	...	4·6	3·5 5·5	2·1	90	16	99·2	
3 1 0	...	...	...	...	...	...	99·3	The right vagus nerve was cut through.
3 1 15	...	...	...	...	...	...	99·3	The left vagus was cut through. The respirations became short and spasmodic.
3 2 0	...	...	...	2·5	60	...	99·4	
3 3 0	...	6·0	5·5 6·0	2·6	...	...	99·3	The mercury in the oscillating column moves very rapidly over short spaces.
3 3 30	...	5·8	5·5 6·2	...	...	...	...	
3 4 0	...	5·8	5·8 6·2	2·5	120	...	99·2	
3 4 30	...	5·9	5·5 6·0	2·5	...	...	...	
3 5 0	...	5·9	5·5 6·0	2·5	125	...	99·2	
3 5 30	...	5·9	5·3 5·8	...	140	...	...	
3 6 0	...	5·8	5·5 5·8	2·5	170	30	99·1	
3 6 30	...	5·7	5·3 5·7	...	166	...	...	
3 7 10	...	5·7	5·7 6·1	...	166	...	99·2	Commenced to inject slowly, into the right jugular vein, seven grains of extract in twenty-five minims of water.
3 7 30	...	...	...	...	...	...	...	Finished the injection.
3 8 0	0 30	5·6	5·0 5·5	...	79	20	99·4	
3 8 30	1 0	5·6	5·0 8·0	...	...	...	...	
3 9 0	1 30	...	4·0 7·0	2·8	50	...	99·3	Respiration spasmodic ; great salivation.

Experiment LXI.—continued.

Time.	Time after administration.	Arterial Tension.		Venous Tension.	No. of Cardiac Contractions.	No. of Respirations.	Temperature.	Notes of Operations and of Symptoms.
		Mean Pressure.	Pressure Oscillates between					
H. M. S.	M. S.				Per Min.	Per Min.	°	
3 9 30	2 0	5·4	4·5 & 7·5	3·2	...	...	99·3	Slight twitches have commenced.
3 9 40	2 10	...	...	3·7	...	...	...	Tears are flowing copiously.
3 10 0	2 30	6·8	5·0 9·0	4·2	45	...	98·5	The respirations cannot be counted, because of the twitching.
3 10 15	2 45	6·9	5·0 9·5	4·5	...	...	...	Fæces passed.
3 10 30	3 0	7·3	5·0 9·5	4·9	...	...	...	Tremors are very strong.
3 10 45	3 15	...	...	5·2	...	...	...	
3 11 0	3 30	6·8	4·5 8·0	5·2	...	...	98·2	
3 11 15	3 45	6·8	4·5 7·5	5·1	...	...	...	
3 11 30	4 0	7·8	6·5 9·5	5 0	...	...	...	
3 11 45	4 15	...	...	5·2	...	...	98·0	
3 12 0	4 30	8·1	6·0 10·0	5 3	42	...	...	
3 12 15	4 45	7·5	6·0 8·0	5·4	...	...	...	
3 13 0	5 30	6·3	5·5 7·5	5·3	56	10	98·2	Respirations are merely gasps.
3 13 30	6 0	5·6	4·0 5·5	...	...	...	...	Neither cornea nor conjunctiva is sensitive.
3 13 35	6 5	4·7	4·0 5·5	5·3	...	...	98·2	Twitches have nearly ceased.
3 13 40	6 10	4·0	...	...	...	...	...	
3 13 45	6 15	3·8	3·0 4·5	5·3	...	...	...	
3 14 0	6 30	3·5	3·0 4·0	5·3	40	an occasional gasp.	98·0	
3 14 30	7 0	3·8	3·0 4·5	5·2	...	...	...	The muscular movements can scarcely be seen, but they can readily be felt.
3 14 45	7 15	3·8	3·0 5·0	4·8	25	Do.	97·7	
3 15 15	7 45	...	...	4·2	...	...	...	
3 15 30	8 0	...	...	3·4	...	...	...	
3 15 45	8 15	...	...	3·0	...	...	...	Urine passed.
3 16 0	8 30	1·5	1·0 1·5	2·4	10	...	...	
3 16 30	9 0	...	...	2·2	...	...	97·6	
3 17 0	9 30	1·0	...	2·2	...	...	...	
3 17 15	9 45	...	...	1·9	...	...	...	
3 17 30	10 0	...	...	1·5	...	...	97·5	
3 17 45	10 15	...	...	1·3	...	...	...	
3 18 0	10 30	...	...	1·0	...	...	97·2	
3 18 30	11 0	..	...	...	...	...	...	
3 20 0	12 30	...	...	...	...	...	97·0	
3 22 0	14 30	...	...	...	...	...	96·8	
3 24 0	16 30	...	...	...	...	...	96·5	

The autopsy was made immediately. Slight, but distinct, peristalsis was observed in the intestines. The heart was dilated and motionless, and its right side contained more blood than in the preceding experiments. The phrenic, intercostal and sciatic nerves were active.

It is, therefore, shown that the same effects are produced on the circulation after the division of the vagi, as when these inhibitory nerves retain their connec-

tion with the heart. The action on the frequency of the heart's beats is well illustrated in this experiment; from their number having been considerably increased before the exhibition of the poison, by the division of the vagi nerves.

The distance over which the mercury travels in the oscillating column seems to be increased as the effects of the poison manifest themselves. This appears from all the experiments in this series, but especially from the second and the last. The division of the vagi, in the last experiment, had abnormally diminished the distance of oscillation; and, yet, it became much greater after the poisoning than it had been previous to the nerve-division. It further appears that this increase in the oscillating distance occurs when the arterial tension is about its maximum. It can only be explained by a very decided increase in the force of the cardiac contractions. I believe that this effect on the heart is altogether a reflex one, due to the resistance to the propulsion of the blood, that the augmentation in the general vascular tension must excite. In a normal condition, a stimulus of this nature might be expected to operate by increasing the *number* and not the *strength* of the cardiac contractions; but any tendency to increased frequency is opposed by the action of physostigma, for we have already seen that this substance diminishes the number of the contractions, by prolonging the diastolic pause. Their strength may, however, continue unchanged; and, during the operation of physostigma, a stimulus may even increase it without affecting the number of the beats, so long as the ganglia that initiate the systolic contraction have their excitability merely lowered without being destroyed and the contractile power of the cardiac muscle continues undiminished.

Before discussing any further the changes of blood tension, it will be advisable to examine the condition of the minute blood-vessels during the action of physostigma.

2. *Examination of the Calibre-Changes in the smaller Blood-Vessels.*

The facility with which frequent measurements may be made of the diameter of any selected capillary or minute artery or vein in the web of the frog's foot, is well known to physiologists, and has been taken advantage of by WHARTON JONES,* BENNETT,† LISTER‡ and others, in examining their condition during inflammation. A more general application of such examination of the capillaries to the investigation of the action of poisons would certainly be of great value. It has proved so in the case of nicotia;§ and we cannot consider any research on the actions of a cardiac poison to be complete unless it be done.

* On the State of the Blood and Blood-Vessels in Inflammation, &c. GUY'S Hospital Reports, 1851.

† Principles and Practice of Medicine.

‡ Philosophical Transactions, 1858.

§ CLAUDE BERNARD, Leçons, &c., 1857, p. 399.

In my first experiments, the frog was merely tied down in the manner usual when the circulation in its web is being microscopically examined, but it was found impossible to prevent movements so absolutely as was required to retain the selected vessels in the field of the microscope. I ultimately found it necessary to adopt LISTER'S recommendation of dividing the spinal cord several hours before the observations were begun.

Experiment LXII.

I divided the spinal cord at the occiput of a light-coloured frog weighing 529 grains, and, six hours afterwards, placed the web of one of its feet on the stage of a microscope. A small artery, a minute branch and a vein were selected and placed conveniently for measurement.*

A = diameter of larger artery; B = diameter of smaller artery; and C = diameter of vein.

Time.	A.	B.	C.	Notes.
15 minutes before administration of Calabar bean	8·0	2·5	6·5	
10 Do.	8·0	2·5	6·5	Circulation free.
5 Do.	8·0	2·5	6·5	
Time after administration of poison.				Four grains of extract, in twenty minims of distilled water, were injected into the subcutaneous tissue of the abdomen.
6 minutes,	7·8	2·5	6·5	
9 ,,	6·5	2·0	6·0	
10 ,,	5·9	1·8	5·7	
12 ,,	6·8	2·0	6·2	Circulation feeble, oscillating sometimes; vessels are crowded.
14 ,,	7·0	2·0	6·5	
15 ,,	8·5	3·0	6 5	
17 ,,	8·5	3·0	7·0	Almost no circulation.
19 ,,	9·0	3·0	7·5	Faint oscillations only in the artery; considerable crowding in all the vessels.
23 ,,	8 5	3·0	7·5	
29 ,,	8·5	3·0	7·5	Complete stasis.
36 ,,	8·5	3·0	7·5	
39 ,,	9·0	3·0	7·5	
1 hour	9 0	3·0	7·5	
2 hours	9·0	3·0	7·5	

Experiment LXIII.

The web of a frog, of 590 grains weight, was placed in the field of a microscope, after the animal had been prepared in the manner described in the previous experiment.

* NACHET'S eye-piece No. 1, and object-glass No. 3, were employed; and the measurements represent divisions of an eye-piece micrometer, each of which equals $\frac{1}{500}$th of an inch with the above glasses.

A = diameter of a small artery; B = diameter of a very small vein.

Time.	A.	B.	Notes.
15 minutes before poisoning,	5·0	3·0	
10 Do.	5·0	3·0	
5 Do.	5·0	3·0	
Time after Administration of Poison.			Two grains of extract, in fifteen minims of water, were injected into the left flank.
5 minutes,	5·0	3·0	
10 „	4·7	3·0	Circulation oscillating.
15 „	4·2	3·0	
20 „	4·2	2·9	
25 „	4·0	2·9	
28 „	4·9	3·0	
29 „	5·7	3·0	
30 „	6·0	3 2	Stasis, and crowded vessels.
35 „	7·0	3·5	Slow circulation.
40 „	7·0	3·5	
45 „	8·0	3·5	Faint oscillations.
50 „	8·0	3·5	
1 hour,	8·0	3·5	
2 hours,	8·0	3·5	

The action of Calabar bean on the minute blood-vessels of the frog's web is, therefore, to contract them considerably first, and then dilate them. The contraction may be influenced, to a slight extent, by the reduction in the frequency of the heart's action; but the succeeding dilatation, during a still greater reduction, would lead us to suppose that it is mainly due to a specific effect on the ganglia and nerves that govern the calibre-changes of the vascular system, because it is by their influence that the final dilatation must be produced.

We are now in a position to explain the changes of blood tension that have been described in mammalians. The slight fall that usually occurs in the mean pressure immediately after the poison has been exhibited, I believe to be solely due to the diminution in the rate of the heart's contractions, which has always been caused by that time. The subsequent rise in both arterial and venous tensions before any considerable embarrassment of the respiration, may be satisfactorily explained by such contraction of the smaller arteries and veins as has been demonstrated to occur in the vessels of the frog's web. It cannot be caused by increased cardiac pressure; for the heart is at the time contracting with only one half its normal rapidity, or with even less; while the greater force of each heart beat the increased oscillating distances appear to indicate, is quite insufficient to account for the high degree of blood tension sometimes attained. The subsequent, more or less rapid diminution of pressure in both arterial and venous systems is the evident result of the great dilatation in the minute blood-vessels, assisted by the weakening of the *vis e tergo* that this poison quickly produces.

Action on the Temperature of the Body.

The temperature of mammalians that are being poisoned by Calabar bean rises slightly, so that a thermometer, placed either in the subcutaneous tissue or in the rectum, will indicate a gradual elevation as soon as well-marked symptoms begin to be produced. The effect on the surface temperature has been already shown in Experiments LIX., LX. and LXI.; that on the internal temperature was frequently observed with rabbits, and may be illustrated sufficiently in the following experiment.

Experiment LXIV.

A full-grown rabbit was placed on its back on a board, and firmly secured by a ligature round each leg.

Time.		Time after Administration of Poison.		Temperature.	Respirations.	Notes.
H.	M.	M.	S.	°	Per Min.	
12	5	...		...	...	The bulb of a delicate thermometer, with Fahrenheit's scale, was secured in the rectum.
12	10	...		99·0	...	
12	20	...		98 5	...	
12	30	...		98·4	...	
12	40	...		98·2	...	
12	50	...		98·0	47	
1	0	...		97·5	...	
1	10	...		97·3	...	
1	20	...		97·0	48	
1	30	...		96·5	...	
2	0	...		96·0	48	
2	10	...		95·8	...	
2	20	...		95·7	48	
2	30	...		95·5	48	
2	40	...		95·5	48	
2	50	...		95·3*	48	
2	56	...		...	...	Half a grain of extract, in ten minims of water, was injected into the subcutaneous tissue of the left flank.
3	1	5	0	95·8	...	Faint tremors of legs and of head.
3	5	9	0	96·3	...	Tremors are now general and stronger; and they prevent accurate determination of the respiratory movements.
3	6	10	0	96·5	...	
3	8	12	0	96·0	...	
3	15	17	0	95·5	...	
3	16	18	0	95·3	72	The muscular tremors have greatly diminished. Respirations are shallow and gasping, and they appear much impeded by bronchial secretion.
3	25	29	0	95·0	...	Quiet; except a few occasional twitches.
3	30	34	0	95·0	24	Respirations are very noisy and laboured.
3	32	36	0	94 5	...	The animal is dead.
3	35	39	0	94·0	...	
3	50	54	0	93·0	...	

* It will be observed that the temperature has gradually fallen in this experiment before the

The inconsiderable elevation of temperature exhibited in these experiments is probably an effect of the general muscular twitching that Calabar bean causes in mammals. It is quite possible that it may be also in part the result of vascular dilatation: but I think the first explanation is sufficient alone; and this additional one seems improbable when we remember that during the dilatation the circulation is extremely sluggish, because of the great diminution in the number of the cardiac contractions that accompanies it.

Action on the Blood.

The blood obtained from animals that have been poisoned by Calabar bean is generally dark in colour, because of the usual cause of death; but if drawn from the left side of the heart after a very large dose of the poison, it has the scarlet hue of arterial blood. It frequently remains semifluid for some time, and then clots loosely. When examined with the spectroscope, no modification has ever been observed in the characters or positions of the normal crurine bands.

In dogs and rabbits, the red blood corpuscles are changed in form, and present various irregularities of outline, among which a well-marked stellar crenation predominates. There can be no doubt that this is an effect produced by physostigma, as I have frequently examined the blood previous to the administration, and found its microscopic characters perfectly normal, and repeated the examination immediately after death, and invariably observed the above modifications. No change is produced in the red corpuscles of birds or frogs, nor in the white corpuscles of any animal I have examined.

For the purpose of detecting any possible effect on the respiratory function of the blood—a subject to which Harley, by his elaborate researches, has directed considerable attention*—two experiments were performed, the results of which agreed very closely. One of these may be given here, but without the numerous details which are necessarily connected with it.

Experiment LXV.

A small quantity of blood was directly removed from the right side of the heart of a Skye-terrier dog, by passing a gum-elastic catheter down the right jugular vein, affixing a syringe with a stop-cock, and withdrawing the requisite amount, according to the ingenious method of Claude Bernard.† The catheter was then detached from the syringe, and, the stop-cock

poison was administered, and apparently because of the constrained position in which it was necessary to retain the rabbit. In other nine experiments of the same description, a similar fall occurred. I endeavoured to find if a stationary, constant point could be obtained, after which the poison might be given; with the following result:—When the thermometer was introduced, the temperature was 97°; in one hour, it had fallen to 96°·3; in two hours, to 95°·6; in three hours, to 95°·3; in four hours, to 94°·7; in five hours, to 93°·3; and in six hours, to 92°. The rabbit was now set free: it was unable to stand; and other four hours afterwards, it was found dead. As this is a very ordinary method of treating rabbits during physiological experiments, it is important to recognise this injury to their vitality, which may occasion many fallacious conclusions if overlooked.

* On the Influence of Physical and Chemical Agents upon Blood; with special reference to the mutual action of the Blood and the Respiratory Gases. Phil. Trans. 1865, p. 687.

† Action de l'Oxyde de Carbon sur le Sang, Leçons, &c., 1857, p. 166.

having previously been closed, a bent steel tube was substituted by which means the blood could be readily passed into a small absorption tube over mercury, without coming in contact with the atmosphere.

The vein was now ligatured, and the dog was poisoned with a moderate dose of the extract. At the moment of death, a second quantity of blood was withdrawn with the same precautions as the first, and it was placed in a similar absorption tube. A nearly equal portion of atmospheric air was added to each tube, and they were frequently shaken during twenty-four hours in a room with a temperature that varied little from 50° F. The gases were then removed and analysed. The following are the results :—

Gases from Blood before Poisoning.		Gases from Blood after Poisoning.	
Volume of blood = 7·77 cub. cent.		Volume of blood = 4·03 cub. cent.	
„ air = 47·95 „		„ air = 48·20 „	
After contact with the blood for 24 hours, air measures 51·65 c. c.		After contact with the blood for 24 hours, air measures 50·54 c. c.	
∴ Apparent exhalation = 3·70 c. c.		∴ Apparent exhalation = 2·34 c. c.	
Composition per cent. :—		Composition per cent. :—	
Oxygen, . . .	20·63	Oxygen, . . .	19·93
Nitrogen, . . .	77·82	Nitrogen, . . .	78·77
Carbonic acid, . .	1·55	Carbonic acid, . .	1·30
	100·		100·

These results agree sufficiently to prove that the respiratory function of the blood is not interfered with in physostigma poisoning. Had there been any marked discrepancy, a suspicion of such an action might be raised; but I doubt if this could be really settled without a much more refined method of experiment than was adopted. HARLEY'S results seem open to very many objections, as his usual method permitted of an even greater number of fallacies than were possible in the two experiments I performed. At the same time, his paper is an extremely valuable and elaborate one, and contains many conclusions of the highest interest to physiologists.

ACTION ON THE LYMPH-HEARTS OF THE FROG.

The lymph-hearts discovered by MÜLLER* and PANIZZA† in amphibia, ha always been found paralysed at an early stage of the poisoning, in the exp ments where their condition was examined. As the pulsations of the pair situa one on each side of the sacrum of frogs may be readily determined without operation, attention was especially directed to them. The time at which cease to contract is noted in the following experiment; and the previous inc in rapidity that is there mentioned has been observed on other occasions.

Experiment LXVI.

The lymphatic hearts in the ischiadic region of a frog had an average rate of fo contractions in the minute. Five minutes after two grains of extract had been subcut

* Philosophical Transactions, 1833, p. 559.
† Proceedings of the Royal Society of London, vol. ix. p. 559.

administered, these contractions were seventy-two; in ten minutes, they were seventy; in fifteen minutes, they were sixty-two; and in twenty minutes, they were forty-four. At this time, the frog was flaccid, though still possessing the power of feeble voluntary movement; and its respiration had ceased. One minute thereafter, or twenty-one after the poison had been given, the most careful examination failed to detect any pulsation of the lymphatic hearts, their final stoppage having suddenly occurred.

In many other experiments, these symptoms merely repeated themselves.

Action on the Peristaltic Movements of the Abdominal Viscera.

A close analogy exists between the action on the minute blood-vessels and that on the peristaltic movements of the intestines. In mammalians, physostigma seems, in the first place, to increase the vermicular contractions of all the abdominal viscera, and then to diminish them. For some time, the intestines move with increased vigour; they then contract, so as very considerably to diminish their calibre; and, finally, they assume a condition of dilatation with lessened movement. Peristalsis has been invariably observed to continue after death; but if a large dose has been exhibited, it may be very slight and of short duration. Stimulation of the vagi nerves sometimes increases vermicular movements after death, and it then does so very conspicuously in the stomach. I have never succeeded in convincing myself of the activity of the splanchnic nerves in post mortem examinations; but, as the intestinal movements are then usually sluggish, it is a matter of extreme difficulty to judge of the action of their inhibitory nerves. During the progress of the symptoms in rabbits, I have also observed very energetic peristalsis in the cornua and body of the uterus, and even in the ureters. From the former of these effects I should be inclined to recommend physostigma as an oxytocic. As with those of the heart, the special ganglia of the intestines appear to have their functions retained, with diminished activity, for a considerable period after death; and, as with the cardiac muscle, stimulation produces non-peristaltic movements of those abdominal viscera that possess a muscular structure, long after the nerves that govern their rhythmical contractions have been paralysed.

Action on the Pupil.

In many experiments, the condition of the pupil was carefully observed, and its diameter was measured at intervals by means of a graduated glass scale, each division of which represented one-fiftieth of an inch.

The changes that usually occur in mammals may be briefly described as consisting of a short period of slight dilatation and a succeeding one of contraction; and either the latter gradually increases until death, or the pupil first oscillates once or twice between dilatation and contraction. The latter condition is present at death, and after this the pupil again dilates.

These iridal movements are best seen in rabbits; they are sluggish in dogs, more so in certain birds, and least evident in frogs.

The more important of the results may be conveniently arranged in the form of a table.

Table of Pupil-Changes during Poisoning by Physostigma.

Experiment.	Animals.	Average before Poisoning.	Minimum after Poisoning, and Time of Occurrence.	Time of Return to Average before Poisoning.†	Dilatation over Average, and Time of its Occurrence.	
No. LXVII.	Frog	3 × 4*	1·75 × 3 in 46 min.	Not noted	None noted	
„ LXVIII.	Do.	5 × 7	4· × 5 in 29 „	4 hours	Do.	
„ LXIX.	Do.	5 × 7	4·5 × 6 in 16 „	55 min.	6 × 7 in 1 h. 10 m.	
„ LXX.	Rabbit	13 long diam.	4 in 7 min.	Not noted	None noted	
„ LXXI.	Do.	9 „	4 in 5 „	15 min.	Do.	
„ LXXII.	Do.	10 „	7 in 11 „	23 min.	Do.	In 23 minutes, when the pupil had returned to its average, the animal had nearly recovered from a small dose; the second line marks the effects produced by a second and larger dose, 24 minutes after the first.
	Same rabbit	10 „	6 in 7 „	Not noted	Do.	
„ LXXIII.	Rabbit	10 „	3 in 12 „	Do.	Do.	
„ LXXIV.	Do.	11 „	3 in 16 „	58 min.	Do.	
„ LXXV.	Do.	9 „	3 in 7 „	8 min.	Do.	
„ LXXVI.	Do.	12 „	4 in 8 „	Not noted	Do.	
„ LXXVII.	Do.	13 „	3 in 8 „	Do.	Do.	
„ LXXVIII.	Do.	11 „	3 in 16 min. 30 sec.	17 min. 30 sec.	Do.	
„ LXXIX.	Frog	4 × 6	3·5 × 5 in 24 min.	Not noted	Do.	
„ LXXX.	Do.	5 × 6	4· × 5 in 25 „	2 hours	5 × 6 in 1 h. 46 m.	Eyelids closed, so that it was difficult to see the pupil after 24 minutes. This often happens in frogs.
„ LXXXI.	Do.	5 × 6	3· × 4·5 in 16 „	2 hours	None noted	
„ LXXXII.	Do.	5 × 6	4· × 5 in 30 „	1 hour 47 min.	Do.	
„ LXXXIII.	Dog	21	17 in 28 min.	29 min.	25 in 30 min.	
„ LXXXIV.	Frog	5 × 6·5	4· × 5 in 19 min.	2 hours 5 min.	None noted	
„ LXXXV.	Do.	4 × 5·5	3·5 × 5 in 11 „	22 min.	Do.	
„ LXXXVI.	Do.	6 × 7·5	3· × 5 in 50 „	Not noted	Do.	
„ LXXXVII.	Dog	21	15 in 4 min.	4 min. 30 sec.	25 in 5 min. 30 sec.	
„ LXXXVIII.	Do.	10	4 in 5min. 30 sec.	8 min.	15 in 10 min.	
„ LXXXIX.	Do.	16	3 in 7 min.	9 min. 30 sec.	None before death	
„ XC.	Do.	15	9 in 11 „	16 min.	None noted	
„ XCI.	Pigeon	6	4 in 8 „	Not noted	None noted	
„ XCII.	Do.	6	4 in 28 „	Do.	Do.	General symptoms were very slowly produced.

* The figures represent fiftieths of an inch. † In warm-blooded animals, the periods entered in this column are generally subsequent to death.

The examination of the cervical sympathetics was resumed soon after the poison was exhibited with the following results :—

In 2 min.		after the administration, stimulation of the left sympathetic with the secondary coil at		190=0 in 30 seconds.
4	„	do.	do.	185=dilatation from 7 to 15 in 10 sec.
10	„	do.	do.	188=0 in 30 seconds.
10	„ 30 sec.	do.	do.	185=dilatation from 5 to 15 in 10 sec.
12	„ 30 „	after the administration, left pupil = 4, right pupil = 5.		
13	„ 30 „	do.	stimulation of the left sympathetic with the secondary coil at	185=0 in 30 seconds.
14	„ 0 „	after the administration, stimulation of the right sympathetic with the secondary coil at		185=0 „
14	„ 35 „	after the administration, stimulation of the left sympathetic with the secondary coil at		160=0 „
15	„ 30 „	do.	do.	90=0 „

The rabbit was now dead, and both pupils had been for more than two minutes previously in a state of extreme contraction.

In 16 min. 10 sec.	after the administration, stimulation of the right sympathetic with the secondary coil at		30 = 0 in 30 seconds.
17 „ 0 „	after the administration, stimulation of the left sympathetic with the secondary coil at		10 = 0 „
18 „ 0 „	after the administration, stimulation of the right sympathetic with the secondary coil at		10 = 0 „

The left iris was at this time exposed by cutting away a portion of the cornea. The electrodes were applied directly to its surface, near the external margin, when a slight and rapid contraction of the iris (dilatation of the pupil) occurred, instantly followed by a rebound to its previous condition. This effect was frequently produced during many minutes after death, but no distinct expansion of the iris (contraction of the pupil) could be caused when the electrodes were applied in the same way to the pupillary margin. It must, however, be added that the pupil was at this time in a very contracted condition.

We learn from this experiment that the cervical sympathetic is paralysed before the death of the animal, while a portion of the apparatus that is immediately concerned in the contraction of the iris retains its vitality for a considerable period afterwards. The cause of the pupillary contraction during poisoning by internal administration is, therefore, in all probability, to be found among those consequences that naturally succeed the removal of the influence of the cervical sympathetic nerve. Without dogmatising on this subject, and feeling content in the meantime with the mere narration of these facts, I am inclined to think that such changes of the iris can only be explained by considering the influences of dilator and constrictor muscles, and also of a system of contractile blood-vessels.

An animal struggles violently during the action of a poison, and the pupil dilates. It is natural to suppose that, in this case, the excited spinal nerves had produced increased action of the dilator muscle, and that thereby the antagonism of the constrictor had been overcome. But if iridal movements are merely the results of spinal or cerebral nerve-force interfering with antagonism between muscles, how account for the continuation of either dilatation or contraction after

the death of these nerves? Such conditions should not exist when the causes of interference with antagonism have been removed. I, therefore, venture (in common with others, and notwithstanding the anatomical difficulties that exist) to include an arrangement of contractile blood-vessels among the causes that produce iridal movements.

These blood-vessels will possess the function of erectile texture, and will act either in harmony with the dilator or constrictor muscles, or independently of them. The coincidence I have frequently observed between changes of blood-tension and differences in the size of the pupil also leads me to support this view. At the same time, the influence of an erectile tissue is not in itself sufficient to account for all the pupil changes; they can never be explained satisfactorily without also considering the effects of spinal and of cerebral motor nerves, operating probably on radiating and circular muscular fibres whose action is independent of such tissue. The cervical sympathetic appears to be the channel through which the nerves that originate in the cilio-spinal region pass to the iris. Stimulation of this region, or of the sympathetic nerve, produces dilatation of the pupil: and this does not interfere with the supposition of the existence of a contractile vascular network co-operating with a proper dilator muscle; for then the blood-vessels of this network, being governed by branches of the same nerves, would contract along with the dilator fibres, and the result would be a diminution in the size of the iris, and, consequently, a dilatation of the pupil. In the same way, division or paralysis of the sympathetic would result in iridal expansion; the contraction of the pupil being caused by dilatation of the blood-vessels, assisted, it may be, by the simultaneous contraction of a circular muscle.

B. TOPICAL EFFECTS.

When applied to the Nervous System.

It is obvious that when a poison is applied during life to the substance of any of the central nerve-organs, it will produce its specific action on the system in the ratio of the absorbing power of the organ, and therefore very much in proportion to the local blood supply. Other distinct effects are, however, frequently caused by the concentrated form and other peculiarities of the preparation. The watery suspension of physostigma extract caused no peculiar symptom when applied to the cerebrum of mammalians, birds, or frogs; and as its absorption was slow when so exhibited, the constitutional effects were produced only after long periods. When it was applied to the spinal cord of frogs, peculiar twitchings occurred in the muscles directly connected by motor nerves with the part of the cord in contact with the poison. These twitches soon ceased, and no movements were then caused when this portion of the cord was galvanised. The first effect was probably the result of local irritation merely, while the final paralysis was due to a specific action of physostigma.

From the nearly complete absence of blood-vessels in the trunks of the sciatic nerves, it is possible to localise the effects of a poison to any portion of the trunk. A curious result was produced by the topical application of Calabar bean. It has been shown that this poison does not appear to paralyse the afferent nerve fibres when acting through the blood; or, at least, that under its influence the function of the motor nerves is indubitably very much sooner destroyed than that of the sensory. When, however, the poison is applied to a mixed nerve-trunk, the order wherein these effects are produced is reversed, the afferent nerves being paralysed a few minutes before the efferent. This may be shown with great distinctness if strychnia be given after the local action has continued for some time.

Experiment XCIV.

The spinal cord of a frog was divided at the occiput, the sciatic nerves were exposed, and a piece of gutta-percha parchment was placed under each nerve, so as to isolate it completely. A small pad of cotton wadding *steeped in water*, was applied to the *right* nerve, while a similar pad *steeped in a concentrated mixture of extract of physostigma and water*, was placed on the *left;* care being taken to prevent the diffusion of any of the extract beyond the parchment. At this time, a slight stimulation of either nerve, below or above the pads, caused contraction of the limb and general reflex movements.

The pads were kept moist by an occasional drop of water on the right, and one of watery extract of physostigma on the left; and they were retained in their positions for an hour and forty minutes. They were then removed, and the left leg was carefully washed with distilled water, so as to remove effectually any extract that might have been adhering to the nerve. They were both tested with galvanism, when movements of the left leg followed the application of the poles to any portion of the exposed left sciatic; but no reflected contraction occurred when the nerve was stimulated below the position that had been occupied by the pad. No change had occurred either in the afferent or the efferent conductivity of any portion of the right nerve.

A drop of solution of strychnia was now applied to the wound that had been made in the neck by dividing the cord. Seven minutes after this, very weak galvanism of any portion of the right sciatic nerve caused a spasmodic shock of all the body. The same current produced a like effect when it was applied to the left nerve above the part that had been occupied by the poisoned pad; *but when it was applied to the poisoned part,* or *lower down,* the muscles below the point stimulated alone contracted, *no reflected movements being caused.* The same effects were repeatedly observed for other six minutes, before the lapse of which time the action of the strychnia had manifested itself more violently, and rendered the above peculiarities more distinct and exaggerated.

This experiment has been several times repeated, and has always yielded similar results.

If the poisoned pad be permitted to remain in contact with the nerve for a few minutes after the paralysis of its afferent fibres has been caused, the motor fibres also will have their conductivity destroyed.

Experiment XCV.

The sciatics of a frog were exposed, and were treated exactly as in the previous experiment. The afferent conductivity of that portion of nerve to which physostigma had been applied was lost in two hours, but the motor conductivity was yet retained. The application was continued, with the result that the conductivity of the motor fibres was destroyed within other fifteen minutes.

When applied to Striped and to Unstriped Muscle.

Although physostigma, when acting through the blood, does not destroy muscular contractility, the contact of a concentrated preparation is immediately followed by very rapid paralysis of the portion of muscle to which it is applied.

Experiment XCVI.

The two gastrocnemii muscles of a frog, and portions of the sciatic nerves in the thighs, were exposed and separated from contiguous structures. The muscles were completely isolated by pieces of parchment. A pad *soaked in a concentrated mixture of extract and water*, was placed on the surface of the right muscle, and a similar pad *moistened with water*, was placed on the left: the muscles being at the time completely under the control of their sciatic nerves, and being readily excited to contractions by direct galvanism.

Four minutes afterwards, a weak galvanic current was applied to the left nerve, and produced energetic contraction of all the muscles supplied by the nerve; and the left gastrocnemius muscle also contracted forcibly when directly stimulated. The same current was then applied to the right nerve, and caused pretty active movements of the right leg; in which, however, the gastrocnemius only sluggishly participated.

In fifteen minutes, the right or *poisoned gastrocnemius was perfectly paralysed; while the left muscle appeared to be as active functionally as when the experiment was commenced.*

The pad soaked in the extract was then removed from the right muscle and placed on the left. In five minutes, the contractility of the latter was considerably impaired; and in twenty minutes, no contraction could be produced, even when it was stimulated by very strong galvanism.

It was found that when a portion of intestine in energetic peristalsis, had its surface painted over with a concentrated watery mixture of the extract, it became flaccid; and that when a vermicular contraction ran along towards this portion, it stopped at the margin of the portion, and appeared to *skip over* it, as the peristalsis was resumed at the nearest unpoisoned point of the intestine. Soon afterwards, the poisoned portion of intestine could not be stimulated to contract by strong galvanism.

When applied to the Heart.

For the purpose of examining the topical effects on the heart, frogs were generally employed, but warm-blooded animals were in a few instances made use of.

The conditions of the experiments were varied by the application of the poison to the visceral pericardium, and to the muscular substance of the heart; without, and after, its removal from the body; and by the insertion of the poison into one of the cardiac chambers.

1. *Without its Removal from the Body.*

a. *To the Visceral Pericardium.*

Experiment XCVII.

The exposed heart of a frog was found, during ten minutes, to have an average rate of seventy beats in the minute.

A drop of filtered concentrated solution of the extract was placed on the pericardium.

In 1 minute, heart = 52 per minute.
2 „ = 40 „
4 „ = 36 „
6 „ = 30 „
8 „ = 24 „
10 „ irregular; eighteen ventricular and twenty auricular contractions.
13 „ „ no ventricular and eleven auricular contractions.
14 „ „ „ „
22 „ = 8 per minute; both chambers contract, but the ventricles very feebly.
25 „ = 12 „
40 „ = 15 „ very feeble, but rhythmical.
50 „ irregular; twelve ventricular and fifteen auricular contractions.
52 „ „ no ventricular and eighteen auricular contractions.

The ventricles did not again contract spontaneously, but the auricular action continued for many hours. Voluntary movements were made by the frog until fifty minutes after the poison had been placed on its pericardium.*

b. *To the Heart.*

Experiment XCVIII.

A portion of the pericardium was removed from the exposed heart of a frog; and, during ten minutes that followed this operation, its contractions varied little from forty-five in the minute. A small drop of the same solution of extract as was employed in the previous experiment was placed on the heart's surface.

In ten seconds, heart = 0.

It continued motionless for thirty seconds; then recommenced; but, almost immediately afterwards, the frog struggled violently, and the contractions again ceased for ten seconds.

In 2 minutes, heart = 27 per minute.
4 „ = 21 „
6 „ = 30 „
8 „ = 34 „ Rhythmical and regular.

At this time, a second drop was applied to the heart.

In 30 seconds, a struggle occurred, and the heart stopped for ten seconds. When it recommenced, the contractions were irregular, only five ventricular to ten auricular occurring in the minute.
In 3 minutes, there were no ventricular movements and 6 auricular.
10 „ „ 20 „
12 „ heart = 23 per minute; rhythmical but irregular.
20 „ „ = 28 „ „ and regular.
40 „ „ = 28 „ „ „

A third drop was now applied.

In 2 minutes after the third application, heart irregular, { no ventricular movement, and 24 auricular.
8 „ „ „ „
18 „ „ = 7 per minute, { both ventricles and auricles contracting.
25 „ „ = 0 „

* In this and in the other experiments of the series, a drop of water was occasionally placed on the heart to prevent its surface from drying.

Experiment XCIX.

A young rabbit was killed, and its heart was exposed. During four minutes, the contractions were eighty per minute. A concentrated solution of extract was painted over the greater portion of the heart's surface. In one minute, the contractions had entirely ceased; but, a few seconds afterwards, the left ventricle spontaneously resumed its action, and in two minutes after the application, the whole heart was contracting at the rate of seventy-six per minute.

The application was thrice repeated with similar results. Latterly, however, a longer interval occurred between the suspension and recovery of the cardiac contractility. Paralysis of the heart was ultimately caused by continuing these applications.

2. *After Removal from the Body.*

When the heart is removed from the body and placed in a concentrated solution of extract, its contractions immediately become irregular, and then cease. All the vital properties of its structures are paralysed in one or two minutes.

3. *Insertion of Physostigma into one of the Heart's Chambers.*

Experiment C.

A young rabbit was killed by the destruction of the medulla oblongata. In four minutes afterwards, while the heart was contracting at the rate of fifty per minute, two grains of extract, in five minims of water, were injected by WOOD'S syringe into the right auricle. The action of the heart instantly ceased. However, during the next ten minutes, irritation could still cause single laboured contractions.

TOPICAL ACTION ON THE BLOOD-VESSELS AND PIGMENT-CELLS WHEN APPLIED TO THE WEB OF THE FROG'S FOOT.

WHARTON JONES has examined with great care the changes in the calibre of the blood-vessels that follow the application of various substances to the frog's web.* Solution of atropia produces a marked contraction, a result that I have had occasion to confirm; and it, in this respect, resembles ordinary stimuli, such as galvanism, temporary cold and heat, and various irritants. He further established, and LISTER has supported and extended the statement,† that the contractile power of minute blood-vessels is independent of the central organs of the nervous system, though it may be controlled by them. A few substances were found that cause dilatation of blood-vessels, and among them solution of opium.

This antagonism in the actions of opium and atropia, and the well-known difference in their effects on the pupil, whether acting through the blood or acting by topical application, seem to have an important bearing on the question of how far the movements of the iris are due to calibre-changes of its blood-vessels. The examination of the topical effects of physostigma—a much more powerful

* On the State of the Blood-Vessels in Inflammation, &c.; *loc. cit.*

† An Inquiry regarding the parts of the Nervous System which regulate the Contraction of the Arteries; Philosophical Transactions, vol. cxlviii., 1858.

myositic agent than opium—is thus not only of great intrinsic interest, but also likely to be of considerable importance in explaining its action on the iris. In the experiments that were undertaken for this purpose, the condition of the pigment-cells also was observed.

Experiment CI.

The spinal cord of a light-coloured, large frog was divided between the first vertebra and the occiput; and, thirty minutes afterwards, a portion of a web was placed on the stage of a microscope.

An artery and three branches were selected for examination (A, B, C and D); and during ten minutes, their diameters occupied pretty constantly the following divisions of an eye-piece micrometer :—

A = 3; B = 2; C = 2; D = 1·5. The pigment-cells were diffusely stellate.

A small drop of filtered watery solution of extract was placed on the web.

In 2 minutes,	A = 3·0; B = 2·0; C = 2·0; D = 1·5.	Pigment-cells	stellate,	Current of blood seems rather more rapid.
8 „	A = 3·0; B = 2·5; C = 2·5; D = 1·5.	„	„	„
15 „	A = 3·5; B = 3·0; C = 3·0; D = 1·5.	„		concentrating.
20 „	A = 4·0; B = 3·0; C = 3·0; D = 1·5.	„		concentrated : no rays.
40 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		„
50 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		diffusing a few rays.
1 h. 0 min.	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		rather more diffuse than at commencement of experiment.
1 „ 10 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„	in nearly extreme diffusion.	Circulation free.
1 „ 20 „	A second drop of the solution was placed on the web.			
1 „ 25 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	Pigment-cells		concentrating.
1 „ 26 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		stellate.
1 „ 30 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		again diffusing.
1 „ 35 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		in extreme diffusion.
2 „ 30 „	A = 4·0; B = 3·0; C = 3·5; D = 2·0.	„		„

Experiment CII.

An artery and two branches (A, B, C) and a capillary (D) were selected in the web of frog, which was prepared as in the preceding experiment. Their diameters were found to be the following—A = 7; B = 6·5; C = 4; D = 1 : while the pigment-cells in the field were in a state of extreme concentration, there being no rays visible.

A drop of a filtered, strong solution of extract was placed on the web.

In 10 minutes,	A = 9; B = 8; C = 5; D = 1.	Pigment-cells	in extreme concentration. Circulation active.
20 „	A = 9; B = 8; C = 5; D = 1.	„	extreme concentration. Circulation active.
40 „	A = 9; B = 8; C = 5; D = 1.	„	stellate. Circulation languid.

The observations were continued until two hours after the application; and, up to that time, no further change had occurred, except that extreme diffusion had appeared in the pigment-cells.

Experiment CIII.

A portion of the web of a frog was arranged for microscopic examination, in the same way as in the two preceding experiments. An artery and two branches (A, B, C) were selected for examination, along with several adjoining pigment-cells.

Before the application, A = 4 ; B = 2 ; C = 1·5 : while the pigment-cells were in the stellate form.

A drop of a filtered, strong solution of extract was placed on the web.

In 5 minutes,	A = 5; B = 2; C = 1·5.	Pigment-cells	concentrated, with a few short rays,	Circulation more rapid; and many capillaries that were before empty now contain an actively moving blood stream.
10 „	A = 5; B = 2; C = 1·5.	„	in extreme concentration.	
20 „	A = 5; B = 2; C = 1·5.	„	„	Circulation continues active.
30 „	A = 5; B = 2; C = 1·5.	„	„	„

The action of physostigma on the calibre of the minute and contractile blood-vessels is thus the reverse of that of atropia.

LISTER believes that the pigment-cells possess a nerve apparatus that governs their condition in exactly the same way as the smpathetic ganglia and spinal nerves govern the calibre-changes of the smaller blood-vessels.* If this be so, the long continued concentration, which precedes the diffused condition of the pigment in these cells, would imply that their nerves are more sensitive to irritation than those of the vascular system, and that this pigmentary concentration is the result of a stimulating property of the extract, of so slight a character as to have no effect on the ganglia and nerves of the blood-vessels.

WHEN APPLIED TO THE EYEBALL, OR TO ITS IMMEDIATE NEIGHBOURHOOD.

As this investigation has been confined to the lower animals, the action on the iris only can be here discussed. This has been observed in amphibia, reptiles, birds, and mammalians. The pupil contracts within a few minutes after the application of physostigma to the eyeball, to the cutaneous surface in its neighbourhood, or to the nasal mucous membrane; and, if the quantity have been considerable, this may last for two or three days. It is caused much more rapidly, and maintained for a much longer time, than the often varying state of contraction that has been described as a symptom produced by physostigma acting through the blood. There is no reason to doubt that it is as purely an effect produced by contact with the iris as the opposite state that atropia causes; and so limited is the action, that in the same animal extreme physos-

* On the Cutaneous Pigmentary System of the Frog; Philosophical Transactions, vol. cxlviii., 1858, p. 627.

tigma-myosis may exist in one eye, while atropia-mydriasis is present in the other. It is easy to prove the presence of the extract within the eyeball, after its topical application, by removing the aqueous humour and placing it on the conjunctiva of another animal, when the usual effects of Calabar bean on the pupil will be produced.

In addition to this phenomenon, increased lachrymation, and congestion of the conjunctiva, and, I believe, of the iris itself, are produced.

The question of the effects produced on the eye by the topical application of such substances as physostigma and atropia must always be an interesting one to physiologists. Its full discussion would require a special paper, so numerous are the data to be considered, and so conflicting the opinions that have been expressed. Besides, there are some effects that can only be conveniently examined in man, and which must be included in any satisfactory review of this attractive subject. It is, however, quite within the purpose of the present investigation to consider the method in which the iris is expanded by physostigma. I have already expressed an opinion that iridal changes appear to require the co-operation of special radiating and circular muscular fibres, with a system of contractile blood-vessels possessing to a certain extent the properties of erectile tissue. A mere antagonism between the two former muscular arrangements could not alone account for the effects of either physostigma or atropia; and, indeed, the actions of those substances seem to oppose such a theory. All the muscular fibres in the iris are unstriped, and physostigma relaxes while atropia contracts such fibres. Therefore, were these the only causes of iridal movement, physostigma would produce no effect on the pupil; for it would merely render less energetic the contraction of both, and would not thereby disturb their counterbalancing antagonism. For a similar reason, atropia will merely increase the opposing action of both, without causing any iridal movement.

To reconcile their actions with this anatomical arrangement, it is necessary to make one of the following very improbable suppositions—that the circular muscle at the pupillary margin has different physiological properties from the dilator; or that the one set of fibres is regulated by nervous ganglia that can be stimulated by the contact of substances, which paralyse corresponding ganglia whose power is limited to the other set.

Let it be granted, however, that dilator and constrictor muscles with counterbalancing powers exist, and that, in addition, a system of contractile blood-vessels is present, and the ascertained physiological actions of these opposing substances will be rendered available for the explanation of their peculiar effects. Dilatation of the pupil by atropia will then be due to the successful opposition of radiating muscular fibres and contractile iridal blood-vessels, to unaided constrictor fibres; the contact of atropia causing contraction of all unstriped fibres,

including those of the blood-vessels: while contraction of the pupil by physostigma will be intelligibly explained by the universal relaxation of all the contractile tissues of the iris, and the consequent enlargement of its area by the increased accession of blood, which the dilated vessels attract and permit.

The topical action of physostigma on the blood-vessels has been already described, and it certainly supports the view just stated. Confirmatory evidence is also obtained from ADAMÜK's recent experiments on intra-ocular pressure,* which show that this is increased by extract of Calabar bean applied to the conjunctiva and diminished by atropia; for such a difference of effect would necessarily exist, did physostigma augment the blood supply of the iris and atropia decrease it.

The additional effects that follow the topical application to the human eye-ball will be mentioned among the general conclusions.

The following are the conclusions of this investigation:—

A. ACTION THROUGH THE BLOOD.

1. Physostigma has proved fatal to every animal hitherto examined, with the exception of the Eséré moth. In mammals and birds, death is most rapidly caused when the poison is injected into the circulation or when it is brought into contact with a wounded surface. It follows nearly as quickly, when Calabar bean is introduced into a serous cavity; much more slowly when it is exhibited by the mucous membrane of the digestive system. In rabbits, death has been caused by its application to the Schneiderian, the auditory or the conjunctival mucous membrane. The skin of frogs resists the poison for a long time; but, if it be applied for a considerable period, and with proper precautions, distinct evidence of absorption may be obtained, though death has never been caused by such application.

2. The contact of the extract of Calabar bean with the gastric juice of a dog, for twenty-four hours and at a temperature a little above 95° F., did not, in the slightest degree, modify the energy of the poison.

3. A large dose, given to a mammal or bird, rapidly affects the cardiac contractions, and then paralyses the heart. The respiratory movements are quickly stopped, but the symptoms and post mortem appearances are those of syncope. Such a dose, injected into the abdominal cavity of a frog, affects nearly simultaneously the heart and spinal cord, and very rapidly destroys the vitality of both organs. In this case the motor nerves are only slightly, or not at all affected, and may retain their conductivity for about thirty hours. Evidence of

* Centralblatt, No. 36, 1866; and RUTHERFORD's Report on Physiology, Journal of Anatomy and Physiology, No. II., 1867.

the vitality of the afferent nerves may be obtained as long as the retained vitality of the spinal cord permits of its diastaltic function being examined.

4. In mammals and birds, an average dose produces symptoms of asphyxia. When administered to frogs, a similar dose impairs the function of the spinal cord, and diminishes the rates of the cardiac contractions and of the respiratory movements; and, soon after, the latter cease. In periods varying from one and a-half to four hours afterwards, the motor nerves are paralysed; this paralysis implicating their endorgans first, and their trunks afterwards. From this it must not be inferred that the nerve is paralysed by a centripetal progression of the poison; the only fact demonstrated being that a direct ratio exists between, on the one hand, subdivision of nerve substance, facilitating contact of the poison, and, on the other, rapidity of paralysing effect. Indeed, division of the nerve trunk, previous to the administration of Calabar bean, delayed the paralysis of the endorgans. The afferent nerves retain their activity as long, at least, as the functions of the spinal cord are not lost. The spinal cord and the motor nerves are generally paralysed at about the same time.

5. When a small, but still fatal, dose of Calabar bean is administered to a frog, the effects are the same as those in the previous conclusion, until they arrive at the stage of paralysis of the motor nerves; after this, an interval of several hours may elapse before the functions of the spinal cord are completely suspended. During this interval the *tactile* sensibility of the afferent nerves is increased: so that, if the ischiadic artery and vein of one limb have been tied before the exhibition of the poison, a slight touch of the skin in the poisoned region, which before the administration of the poison caused no effect, will now produce faint twitches of the limb whose vessels are tied; while an ordinary excitant, such as sulphuric acid, will show everywhere a marked diminution in the diastaltic activity, as measured by the métronome.

6. *With a still smaller dose, a frog may have its cardiac contractions reduced by from seventy to eight per minute, its respiratory movements completely stopped, and the endorgans of its motor nerves paralysed, and yet afterwards completely recover.* This has occurred when two grains of extract were administered to a frog, weighing 730 grains.

7. In frogs, the voluntary muscles are unaffected by the poison, and may continue to respond to galvanic stimulation during three or four days after its administration. The contrast between this and the effect of Calabar bean on the motor nerves, may be well shown by ligaturing the ischiadic vessels of one limb before injecting the poison. If, when strong stimulation causes no reflex movement, the two gastrocnemii muscles with their attached nerves be so placed that an interrupted current, from one DANIELL'S cell and DU BOIS REYMOND'S induction apparatus, may be transmitted simultaneously through either both muscles or both nerve trunks, it will be found in the case of the

muscles that when the secondary coil is slowly advanced contractions will occur with the same current in both muscles, or with a weaker current in the case of the poisoned than in that of the non-poisoned one, this varying with the length of time which has elapsed since the limb was deprived of blood; when the current is transmitted through both nerves, contractions will be produced simultaneously in both muscles, or with a weaker current in the non-poisoned one, or contractions will occur in the non-poisoned muscle only, this also varying with the length of time that may have elapsed since the exhibition of the poison.

8. In mammals and birds, the voluntary muscles are affected in a very remarkable manner. At an early stage of the poisoning, faint twitches occur, which gradually extend over the body, and, at the same time, increase in vigour so as to interfere with the respiratory movements. Shortly before death, they again become mere successive twitches, often requiring the use of the hand to discover their existence. After death, if a muscular surface be exposed, these twitches will still be observed, involving usually different muscular fasciculi at different times, rarely the whole of a muscle at once; and in mammals they may persist for more than thirty minutes after death. They are caused by a direct effect of physostigma on the muscular substance. This is shown by their continuing after paralysis of the motor nerves, by their persisting in a muscle cut out of the body, and by their non-occurrence in parts that have been separated by ligature from the circulation.

9. In mammals and birds, when the dose is large, the heart's action is rapidly made slower and then stopped. In dogs, it may diminish to one-half in three minutes, and cease in ten. In frogs also, a large dose, injected into the abdominal cavity, causes rapid and complete cardiac paralysis. A smaller dose causes either a gradual cessation followed by a renewal at a diminished rate, or a gradual fall, from sixty or seventy to four or six beats per minute, followed by a gradual return to a diminished rate of from eight to twenty per minute. At this stage, and for many hours afterwards, the only signs of vitality are this diminished cardiac action and the power of the voluntary muscles to respond to galvanic and other stimulation. In the frog, where alone these last phenomena have been observed, the heart may continue so to contract for three or even five days, provided the temperature of the apartment be as low as 50° F. After stoppage, galvanism may sometimes cause a renewal of rhythmical contractions; but this can rarely be done, and unrhythmical and partial contractions can alone be excited. Cessation of the heart's contractions occurs in diastole, with all the chambers full.

10. The pneumo-gastric nerves retain their inhibitory power over the heart during the whole time from the diminution to the partial recovery of its action. Soon after this, however, they are paralysed; and this occurs at nearly the same time as the affection of the motor nerves.

11. Division of the pneumo-gastric nerves, or their paralysis by curare, or destruction of the medulla oblongata or spinalis, does not protect the heart from the action of physostigma.

12. The lymphatic hearts of frogs poisoned by Calabar bean soon cease to contract.

13. In rabbits, a large dose paralyses the cervical sympathetic nerves, before the death of the animal. A smaller fatal dose merely diminishes their activity.

14. Before the stoppage of the heart, proofs may be obtained of the vitality of its sympathetic ganglia; but, as striped muscle is not affected by Calabar bean conveyed by the blood, we are obliged to infer from the symptoms respectively produced, that the activity of the cardiac sympathetic system is probably destroyed by a large dose, and lessened by a smaller one.

15. The animal temperature, both external and internal, has been invariably observed to rise in rabbits and dogs, but only slightly and for a short period; after which it slowly falls.

16. The condition of the capillary circulation was examined in the web of the frog. Soon after the exhibition of the poison, the smaller arteries and veins contracted slightly; but, after a short interval, this contraction was succeeded by a rapid and permanent dilatation, in which the calibre of the vessels was considerably above their maximum previous to the poisoning. This capillary dilatation appears to occur all over the body, as is shown by a peculiar blue coloration of the voluntary muscles and of the heart, a similar coloration of the serous and fibro-serous tissues, and a congestion of the blood-vessels in the conjunctiva and iris. This change also occurs, in a less marked manner, in birds and mammals.

17. The general results of experiments in which the arterial and venous tensions were examined were, that the arterial tension first diminished slightly, immediately after the administration of the poison, then gradually increased until it reached its maximum—when the number of cardiac contractions had diminished to at least one-half,—and afterwards rapidly fell; and that the venous tension began to increase immediately after the administration, continued doing so until it slowly reached its maximum—when the arterial tension had considerably diminished,—and then fell, though more gradually than the tension of the arterial system. The number of the cardiac contractions when the venous tension had attained its maximum, was about one-third of the average before the poisoning; the respirations were rather less frequent than before, and the temperature had risen a few tenths of a degree.

18. Physostigma causes extreme diffusion in the pigment-cells of the frog's skin, and thus a very marked change occurs in the colour of the animal during the progress of the symptoms.

19. In dogs, the peristaltic action of the intestines is usually destroyed at death; it may, however, continue a short time afterwards. In rabbits, the intes-

tinal movements are frequently increased in activity before death, and generally continue for a considerable time afterwards.

20. The pupil contracts in all cases of rapid poisoning in mammalians and birds. The contraction may, however, be slight and of short duration; and dilatation may then be observed during the greater portion of the experiment, especially if the dose be a small one. Contraction of the pupil is produced in frogs also.

21. Calabar bean acts as an excitant of the secretory system; increasing the action of the alimentary mucous, of the lachrymal, and of the salivary glands.

22. In the frog, the symptoms of poisoning are not materially altered by removal of the brain, or by division of the cervical portion of the spinal cord.

23. Artificial respiration does not prevent death, in mammals, after the exhibition of a poisonous dose. This is a necessary result of the effects of physostigma on both the cerebro-spinal and sympathetic systems.

24. Congestion of internal organs occasionally occurs; but this is by no means an invariable consequence of a fatal dose.

25. The blood is generally dark after death, but becomes arterialised on exposure to the air; its respiratory capabilities are unaltered; it often clots loosely and imperfectly; and, when examined with the spectroscope, the bands of scarlet crurine are found unchanged. In the rabbit and dog, a microscopic examination demonstrates an invariable change in the coloured corpuscles, which have their outlines distinctly crenated. This change is not caused in the blood of birds or amphibia. The white corpuscles remain unaltered.

B. TOPICAL EFFECTS.

1. When the poison is applied to the surface of a frog's brain, no effect is produced; but when it is brought into contact with the spinal cord, a few twitches occur in the extremities, followed by paralysis of the portion of cord acted upon.

2. When physostigma is applied to a mixed nerve-trunk, in a concentrated form and with proper precautions to prevent absorption by neighbouring parts, first the afferent nerve-fibres are paralysed, and afterwards the efferent.

3. Topical application destroys the contractility of striped and of unstriped muscular fibre. The heart's action is stopped by repeated application to its external surface or to the pericardium. If a small quantity be injected into one of its chambers, paralysis nearly immediately follows.

4. The blood-vessels are dilated when a solution is applied to the web of the frog's foot.

5. The effects of the application of Calabar bean to the eyeball are a somewhat painful sensation of tension in the ciliary region, contraction of the pupil, myopia and astigmatism; with, frequently, congestion of the conjunctival vessels, pain in the supra-orbital region, and twitches of the orbicularis palpebrarum muscle.

3.

ON THE

DEVELOPMENT OF THE OVA

AND

STRUCTURE OF THE OVARY IN MAN AND OTHER MAMMALIA.

BY

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XVII.—*On the Development of the Ova and Structure of the Ovary in Man and other Mammalia.* (Plates XXVII.–XXXI.)

By James Foulis, M.D. (Edin.) Communicated by Professor Turner.

(Read 21st December 1874.)

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In the month of August 1872, Professor Turner suggested as a subject of investigation the structure of the ovary, and development of the ova, more especially with reference to the recently published observations of Waldeyer.

In the month of April 1874, I handed in to the Medical Faculty of the University of Edinburgh, as my graduation thesis for the degree of M.D., an essay entitled "Contributions to the Normal and Pathological Anatomy of the Ovary and Parovarium."

Accompanying this thesis, were numerous microscopic preparations of the human fœtal ovary, by means of which I was able to demonstrate my descriptive remarks on the anatomy of the organ. Since that date I have made many additional observations on the anatomy of the ovary, especially in connection with the development of the ova, and the formation of the membrana granulosa; and in the present memoir the result of my observations is given. During the last eighteen months, I have made numerous microscopic preparations of the ovaries of various fœtal and adult animals, most of which I now possess, and a careful examination of these verifies my earlier statements on the development of the ova, and the structure of the ovary.

It is not my intention to give a lengthened account of the views of earlier observers on the development of the ova and the structure of the ovary. It may, however, be interesting to notice the following points in the history of this subject.

Previous to the time of De Graaf, the ovary and testicle were considered

identical in structure. In 1671, DE GRAAF introduced the word ovary, and described the Graafian vesicles as ova, which he said were produced in the ovary. The distinction between the true ovum and the Graafian vesicle was not made out till the year 1824, when Messrs PREVOST and DUMAS, by numerous observations, were led to the conclusion that the ova were contained in the Graafian vesicles before conception. The mammalian ovum itself was discovered by VON BAER in 1827, and in 1834 COSTE and others discovered the germinal vesicle in the mammalian ovum. In 1835, WAGNER demonstrated the germinal spot and established the doctrine of a general uniformity in the structure and mode of origin of the ova of animals.

The discussions in the numerous works which appeared between the years 1835 and 1838 turned more or less on the question whether the germinal vesicle, or the ovum itself was first formed, or whether the Graafian vesicles were first produced, and the eggs subsequently developed in them. In MÜLLER'S "Archiv. für Anatomie und Physiologie," 1838, there is a paper by VALENTIN, on the development of the Graafian follicle in the ovary of mammals. He described the Graafian follicles as being formed within long tubes which originally constituted the special structures of the ovary, as the seminiferous tubes do of the testicles, but which become obliterated by the increasing growth of the Graafian follicles.

MARTIN BARRY, by his numerous observations, was led to the conclusion that the germinal vesicle is the part which first makes its appearance in the stroma of the ovary at the commencement of the formation of the ova.

VALENTIN, BISCHOFF, and others, held the view that the Graafian follicles may be detected in the stroma of the ovary before any part of the ovum can be distinguished.

It was with the appearance of PFLÜGER'S work that the views of the structure of the ovary and development of the ova took a new turn. VALENTIN, in 1838, as already observed, first demonstrated the branched and tubular glandular structure of the ovary; an observation which BILLROTH corroborated. Little attention, however, was paid to this observation until it was rediscovered by PFLÜGER, who in a detailed monograph developed his views respecting the structure of the ovary.

In the first place, PFLÜGER showed that the Graafian follicles with the eggs do not appear individually and independently in the stroma of the ovary. He described tubes as passing from the surface of the ovary down into the stroma, composed of a structureless membrana propria, by the inflections of which the several Graafian follicles are successively divided off.

PFLÜGER, (as quoted by WALDEYER),* stated that the tubes lying close beneath the surface of the ovary terminate by cœcal extremities, and in these

* STRICKER'S "Handbuch der Gewebelehre," article Ovary, by WALDEYER, translated by Mr POWER.

the germinal vesicles originate surrounded by a diffuse protoplasm, that forms a more definite investment for each as they become more deeply situated with the tube. Thereupon a number of the cells become conspicuous by their more vigorous growth, whilst the rest remain unaltered, and form the epithelial lining of the tubes. The larger cells, which are primordial eggs, occupy the axis of the tube.

These subsequently increase in number by fission and budding, the products constituting the definite eggs that for a time remain connected with one another in the interior of the tubes in the form of a chain, by processes of protoplasm, constituting the "egg chains" of PFLÜGER. The membrana propria outside the epithelial lining of the tubes sends in processes between the individual eggs, in consequence of which the latter are gradually separated from each other along with a portion of the tubular epithelium; the latter forms the epithelial lining of the Graafian follicles in this way produced. PFLÜGER, in one of his figures (plate iii. fig. 1), has represented a connection existing between his tubes and the superficial columnar epithelium, and has frequently remarked that the contents of the egg tubes must proceed from the ovarial epithelium, which he always considers to be a serous epithelium.

The most important work published within the last few years on the development of the ova and ovary is that by W. WALDEYER, entitled "Eierstock und Ei." (Leipzig, 1870).

According to WALDEYER, the first appearance of the ovary consists of a thickened germ epithelium investing a small outgrowth rich in cells, which projects from the interstitial tissue of the Wolffian body on its median side. The thickened epithelium investing this outgrowth gradually forms the rudiments of the Graafian follicles and ova, and of the subsequently appearing epithelium of the ovary, whilst the outgrowth itself is destined to furnish the vascular stroma of the ovary.

In the embryo of fowls, WALDEYER states, the interesting observation may be made as early as the fourth day of incubation, that some among the germ epithelial cells have become conspicuous by their round form, their size, and the size of the nucleus they contain. We may conclude, from the regular arrangement of these structures and the constancy of their position, that they represent the youngest primordial ova, which thus, even during embryonic life, are formed by a simple process of growth from the epithelial cells of the germ organ. The further development of the ovaries depends on a peculiar mode of growth of the superficial epithelium on the one hand and of the vascularised stroma on the other. Certain more or less delicate processes of the connective tissue now shoot forth from the stroma, whilst coincidently the epithelium increases by the continual production of new cells. The processes then penetrate between the epithelial cells, enclosing a variable number of them, which

thus by degrees come to be more or less deeply imbedded in the vascular stroma. From the plan and mode in which these changes take place it is evident that the several epithelial masses must be connected with each other in a plexiform fashion, and consequently that the ovary at this period of development is composed of a framework of connective tissue, the meshes of which communicate freely as in a cavernous tissue. Some, and sometimes many, among the imbedded epithelial cells become conspicuous by their size and the size of their nuclei, as we have already seen to occur amongst the superficial epithelial cells. Other cells remain of small size, and surround the larger cells as a kind of epithelium. The connective tissue stroma between the imbedded masses of epithelial cells constantly undergoes increase, and especially grows in between the several egg cells with their epithelial investment. Thus each epithelial ball is divided by these ingrowing vascularised trabeculæ into as many cavities as it contains egg cells.

In describing the ovary of a newly born child, WALDEYER thus states, in reference to its tubular structure, "One sees long branching formations in the form of tubes, anastomosing with each other, as VALENTIN first described, and lying separate from each other at considerable distances. They pass upwards opening with narrow mouths into the epithelium, and appear as direct tubular gland-like processes of it.

"At the time in which the tubes described by PFLÜGER exist, that is, as far as I can find, from the ninth month till a short time after birth, they present the structure ascribed to them by PFLÜGER, with the exception already mentioned, that there is as little of membrana propria in them as there is in the primary follicles. In the tubes, and mostly in the middle of them, as PFLÜGER described, we meet with egg cells distinguished by their size and form, often immediately concatenated one behind the other. Whether in the tubes new egg cells are formed, I cannot decide; but I think it likely, because here, as well as on the surface epithelium, some epithelial cells may develope into egg cells. Division of the egg cells in the tubes PFLÜGER seems to have observed, but I have not seen it in fresh specimens."

Follicles are formed from the tubes as well as from the egg compartments, directly through the growth of interstitial tissue. At the lower end of the tube, as may be well explained from the want of a membrana propria, interstitial tissue grows into the tubes and encloses the individual egg cells along with a portion of the not fully developed epithelial cells which surround them, and in this way primary follicles are produced.

In summing up WALDEYER thus remarks:—

"As the chief result of my investigations, it must be stated that both the egg and the follicular epithelial cells are derived directly from the germ epithelium. There is a reciprocal growth of vascular connective tissue and germ

epithelium cells, in consequence of which large and small masses of the latter become imbedded more and more in the stroma of the ovary. The imbedded cells present a variety. Some of them, by simple increase in size, grow into ova, viz., primordial ova, while others keep to their original size, and by numerous divisions, at least as it appears to me, produce still smaller cells, viz., the follicular epithelial cells. A genetical distinction between primordial ova and follicular epithelial cells has consequently no existence. The germ epithelium is the common source of both. The first origin of eggs cannot be looked for in the ovary, but dates much farther back, even to the beginning of embryonic life.

The tubes of VALENTIN and PFLÜGER can lay claim only to a secondary importance, and are not essential for the egg and follicle formation; the greater part of the follicles have undoubtedly an earlier existence, long before these tubes are formed."

In the following description of my observations on the development of the ova and structure of the ovary, I shall in the first place state what I have seen in the fœtal calf, then describe the ovary in young kittens, afterwards give an account of what I have observed in the human ovary, make some general observations on the development of the membrana granulosa in adult ovaries, and conclude with a few remarks on the structure of the ovum.

The drawings in illustration of this paper are all original, and have been carefully prepared, by the aid of the camera lucida, from microscopic preparations in my possession.

THE OVARY OF THE CALF.

If thin sections are made through the ovary of a fœtal calf of about nine inches in length, the following appearances may be recognised in them. A section of such an ovary presents for examination two parts,—an external cortical or parenchymatous part (fig. 1, *a*), and an internal fibro-vascular part (*b*, *b*). The latter is directly continuous with the peduncle or stalk to which the ovary is attached at the hilum (*c*, *c*). On the surface of the peduncle, above and below, is a layer of epithelium (*d*, *d*) directly continued from the peritoneal epithelium towards the ovary; and when the layer is detached from the stalk or peduncle, and examined under high powers of the microscope, it is found to consist of small corpuscles, with large, clearly-defined, oval-shaped nuclei (fig. 2, *e*). Many of the nuclei contain granular matter in their interior. Each nucleus presents a sharply defined wall. In their largest diameter the nuclei measure about $\frac{1}{2500}$th of an inch. The protoplasm round each nucleus is very clear and transparent. Between the nuclei are seen delicate lines, indicating apparently the surfaces of contact of the contiguous corpuscles. The clear substance round some of the nuclei is so small in quantity that the nuclei are almost in

contact; but in other instances it is in considerable quantity, and the nuclei are proportionally distant from each other.

When such a layer of epithelium is seen in profile (fig. 3, *f*, *g*, *h*), it consists of nuclei as before described, placed close to each other. Around each is a quantity of clear protoplasm, which abuts against that of its neighbour. The nuclei are arranged in a single layer, and as we approach the ovary they become placed closer and closer together, and more columnar in form, and the protoplasm investment of each becomes gradually less and less in quantity till we reach the actual surface of the ovary at the lower border, where we find the nuclei crowding together and continued on to the surface of the ovary in the form of the germ epithelium. As the nuclei pass on to the surface of the ovary they are no longer arranged in a single layer, but crowd one on the top of the other, and it is then not possible to say where peritoneal epithelium ends and germ epithelium begins.

All round the ovary the germ epithelium consists of a thick layer of corpuscles. Each corpuscle is a nucleus surrounded with a thin film of protoplasm.

On the upper and lower surfaces of the stalk, as seen in section, the peritoneal epithelium is continuous with the germ epithelium at the lower borders of the ovary in the manner described. The germ epithelium consists of corpuscles (fig. 4, *h*, *h*, *h*), arranged in the form of a thick layer passing round the ovary from one lateral border to the other, and gradually thinning off as it passes into and becomes continuous with the peritoneal epithelium.

The corpuscles of the germ epithelium vary considerably in size and shape; some are round, others oval or columnar, some are twice as large as their neighbours. The greater number are spherical, and within the larger ones a distinct spot or nucleolus is seen. Many of the corpuscles may be seen undergoing division into two or more parts. By this process of fission the corpuscles are ever producing new elements, which in their turn produce similar ones.

The largest germ epithelial corpuscles measure about $\frac{1}{2000}$th of an inch in diameter. In several instances among the germ epithelial corpuscles on the surface of the ovary, I have observed some individuals flattened from above downwards, and the protoplasm round the nucleus drawn out at both ends in such a manner as to present the appearance of a fusiform corpuscle, or peritoneal epithelial cell seen in profile (fig. 4, *i*.)

Below the germ epithelium the cortical zone of the ovary consists for the most part of corpuscles which resemble very closely the germ epithelial corpuscles. A careful examination of this part of the ovary shows that from the deeper or fibro-vascular zone delicate bundles of young connective tissue with blood-vessels (fig. 4, *j*, *j*, *j*) pass upwards among the corpuscles in a radiating manner towards the germ epithelium; offshoots proceed in various directions from these bundles, and give rise to the formation of irregular-sized

meshes of vascular connective tissue, in which are enclosed large and small groups of corpuscles.

In the cortical zone such groups of corpuscles are found under the germ epithelium all round the ovary, and in many situations they are in connection superiorly with the corpuscles of the germ epithelium. At this stage of development the germ epithelium cannot be separated by any distinct line of demarcation from the masses of corpuscles which are below it, but at a later stage the germ epithelium rests on a thin irregular stratum of young tissue. This stratum is part of the fibro-vascular stroma of the ovary, and is formed by the growth of that tissue round the groups of corpuscles, which at an earlier stage of development are found in connection with the germ epithelial corpuscles all round the ovary.

Tracing downwards the bundles of vascular tissue which lie between the groups of corpuscles, we come to the fibro-vascular zone of the ovary (fig. 1, *b*). It must be understood that there is no boundary line between the cortical and fibro-vascular zone; the division is more or less artificial, but it is certain that the cortical, and by far the greater part of such a young ovary, consists of corpuscles with a few bundles of vascular tissue intermingled, while the deeper fibro-vascular zone, as its name implies, consists of very vascular tissue arranged in the form of a mesh-work, and in these meshes are included large corpuscles in various sized groups.

In this fibro-vascular zone we find numerous blood-vessels anastomosing freely with each other (fig. 5, *k*, *k*); the blood-vessels everywhere lie in the midst of bundles of young connective tissue. In the smallest meshes of fibro-vascular tissue generally one large corpuscles is found (fig. 5, *m*). The largest corpuscles consist of a central, large, bright nucleus with a nucleolus; the nucleus presents a sharply-defined double-contoured wall, and is surrounded by a considerable quantity of protoplasm, in contact with which are several very small corpuscles, forming a sort of wreath round the large corpuscle. Immediately outside this wreath is the vascular tissue of the stroma. Many of such large bodies as are now described lie imbedded throughout the fibro-vascular zone of the ovary, especially in its deeper parts; more superficially, many large bodies, but generally without the wreath of smaller corpuscles, are found in the meshes of the stroma; and as we pass upwards in our examination of the cortical zone, we find the fibro-vascular tissue decreases in quantity, but the corpuscles become more numerous, though smaller, till we reach the germ epithelial layer, which consists entirely of corpuscles.

From this description of the appearances presented in a section of the ovary of a very young fœtal calf, we learn that the greater part of the parenchymatous zone of such a young ovary consists of corpuscles very similar in appearance to the corpuscles of the germ epithelium. From the deeper parts

of the ovary delicate bundles of vascular tissue proceed upwards in all directions among the corpuscles, which thus become included in groups in the meshes of the stroma. All round the ovary, under the germ epithelium, groups of corpuscles from the germ epithelium are being imbedded in the stroma by the growth of vascular connective tissue round them. The largest corpuscles are situated most deeply in the stroma, and are in an advanced stage of development, while those more superficially imbedded are in a less advanced stage of development; the youngest corpuscles are immediately under, and in connection with the germ epithelium. The most deeply imbedded corpuscles have already assumed the character of primordial ova, and among the others we can trace many in course of development into similar bodies. In each primordial ovum the nucleus becomes the germinal vesicle, and the protoplasm which surrounds it gradually forms the yelk of the mature ovum.

The Ovary of the Kitten.

I shall now describe the structure of the ovary and the development of the ova in a kitten of two or three weeks; and I may here remark, that I know of no animal better suited than the kitten to show the relation of the germ epithelium to the stroma of the ovary. A section of a young kitten's ovary presents a form similar to that of the young calf's ovary.

In a thin vertical transverse section of a two weeks' old kitten's ovary we may distinguish

1st, The germ epithelium.
2d, The zone of egg clusters.
3d, The fibrovascular stroma.

The germ epithelium consists of distinct corpuscles arranged in a layer which passes round the ovary from one lateral border to the other, and becomes continuous with the peritoneal epithelium which covers the stalk or peduncle.

The corpuscles of the germ epithelium (fig. 6, *h*, *h*) consist of clearly defined nuclei, all of which have a thin investing film of protoplasm. In some instances this protoplasm is very clearly made out, and is in considerable quantity, but in other cases it can scarcely be seen, even under very high powers of the microscope. As in the ovary of the fœtal calf, there is a constant proliferation of the germ corpuscles by a process of fission. They are somewhat granular, and vary considerably in size; some are oval, but the greater number are spherical. In the ovary of a kitten of four weeks the corpuscles of the germ epithelium appear columnar in form and compressed laterally. In the round or spherical corpuscles (*l*, *l*), which are generally larger than the others, the nucleus is extremely well marked, and frequently possesses a bright nucleolus. The spherical form of the larger corpuscles appears to be produced

by the swelling out of the nucleus. In the two weeks' old kitten the corpuscles of the ovarian germ epithelium are several deep, and the layer itself is of irregular thickness.

As we examine the layer of germ epithelium as it passes round the ovary, we are at once struck by the fact that the corpuscles present a great variation in size and degree of development. Here and there we see large spherical nuclei (*l, l, l*), having round them a thin investing layer of protoplasm, while in other situations certain individual corpuscles stand forth prominently among their neighbours, and are conspicuous by their size and the size of their nuclei (*m, m.*) In these latter the protoplasm surrounding the nuclei is in the form of a thick layer. Between these largest corpuscles and the ordinary small ones every variety in size and form is to be met with. The largest corpuscles, which present so much protoplasm round the nucleus, are evidently individuals which have reached an advanced stage of development. These have been termed primordial ova, and there can be no doubt that a great number of the larger or spherical germ epithelial corpuscles are developing into similar bodies.

The ordinary sized germ epithelial corpuscles measure about $\frac{1}{2500}$th of an inch, while the primordial ova measure about $\frac{1}{1000}$th of an inch, but these measurements vary.

On carefully examining the primordial ova, in many instances two or more small fusiform corpuscles are seen in close contact with their yelk or protoplasm.

These fusiform bodies are about the size of the smallest germ epithelial corpuscles, and appear like connective tissue corpuscles, and in more than one case I have traced them in direct continuity with delicate bundles of minute fusiform bodies, which will presently be described as passing up from the deeper parts of the ovary towards the germ epithelium. In other cases, however, it appears to me that the bodies which lie in contact with the protoplasm of the primordial ova are germ epithelial corpuscles which have been displaced, pushed aside, or flattened out during the growth of the primordial ova. No cell wall can be made out round these primordial ova, but in certain sections one frequently sees a thin irregular stratum of a hyaline substance passing round the young ovum in contact with its protoplasm, apparently growing up from the young connective tissue subjacent to the germ epithelium. In this hyaline substance two or three oval-shaped nuclei are seen. In some preparations the primordial ovum has tumbled out of its hyaline girdle, which remains like a ring standing up among the germ epithelial corpuscles.

In favourable specimens, in a single section of a three to four weeks old kitten's ovary, I have counted as many as from thirty to forty large primordial ova among the ordinary germ epithelial corpuscles on the surface of the ovary. They may be recognised at once, for they appear like giants among their neighbours. Each consists of a large spherical nucleus, surrounded with a con-

siderable layer of protoplasm; it is this latter substance which gives magnitude to the young ovum, as may be seen by the fact that though many of the nuclei of the larger germ epithelial corpuscles are nearly as large as the nuclei of the primordial ova, yet, being without the extensive investment of protoplasm, they do not appear markedly conspicuous among the rest like the primordial ova. Occasionally, two large spherical nuclei or germinal vesicles are found in a single large primordial ovum among the germ epithelial corpuscles on the surface of the ovary.

Among the germ epithelial corpuscles in the deeper parts of the germ epithelial layer all round the ovary we meet with many large primordial ova, and in contact with their yelk or protoplasm are small fusiform bodies, each consisting of an oval-shaped nucleus, around which is an investment of protoplasm drawn out at either end in a fusiform manner. Besides these primordial ova, numerous germ epithelial corpuscles, in various stages of development into the same, are found in this situation.

Immediately subjacent to the germ epithelial layer is the zone of egg clusters. In osmic acid preparations this can be seen with the naked eye as a well-marked thick layer. The egg clusters are large oval-shaped and spherical collections of round corpuscles (*o, o, o*). The oval-shaped clusters lie close together, with their long axes directed from the centre of the ovary in a radiating manner towards the germ epithelium. Between the clusters, and separating them, are delicate bundles or strings of small fusiform corpuscles, with blood-vessels (*j, j, j*), which may be traced growing upwards from the deeper parts of the ovary towards the germ epithelium. By far the greater number of the egg clusters are oval, but spherical-shaped groups or clusters are also met with, generally deeper in the ovary. Each egg cluster consists of a collection of corpuscles, most of which are spherical, and resemble very closely the larger corpuscles of the germ epithelium. If we direct our attention to any one egg cluster, it will be seen that the corpuscles vary in size, just as we described the corpuscles of the germ epithelium. At the lower part of each egg cluster, that is, farthest away from the germ epithelium, we find many large primordial ova, similar to those already described among the corpuscles on the surface of the ovary, and besides these are numerous large spherical nuclei, having round them protoplasm in layers of varying thickness. In each egg cluster it is possible to trace the corpuscles in all stages of development into primordial ova. Every large corpuscle in each egg cluster is potentially a primordial ovum. In contact with each primordial ovum in the egg clusters are small fusiform corpuscles, which may be traced as offshoots from the bundles of similar corpuscles which lie between and separate the egg clusters from each other. It is easy to compare the corpuscles in each egg cluster with the corpuscles of the germ epithelium, and to follow the steps of their development into primordial ova.

In such a young kitten's ovary many of the egg clusters are still in connection superiorly with the corpuscles of the germ epithelium, but in most cases, we find the bundles of young connective tissue which lie between the egg clusters have grown completely round them, separating them not only from each other, but also from the germ epithelium above. While the corpuscles of the germ epithelium are thus being enclosed in the meshes of young connective tissue, the nucleus of each swells out into a spherical body, around which is gradually produced that protoplasm which later constitutes the yelk of the primordial ovum.

When we trace the bundles of young connective tissue downwards, we find they are offshoots of similar tissue of which the central part of the ovary consists. In the deeper parts of the ovary we find a very vascular young connective tissue forming the stroma of the organ, in which are imbedded numerous primordial ova, some in a far advanced stage of development. This stroma consists of minute fusiform corpuscles and blood-vessels. As the vascular bundles or strings of this tissue grow upwards between the egg clusters, delicate offshoots of the same insinuate themselves between the primordial ova and corpuscles in the clusters, and in this manner nourishment is brought within reach of these developing bodies. This interstitial growth begins at the lower part of each egg cluster, and gradually the primordial ova become separated from each other as the connective tissue thickens in between and around them, and they become at last included in separate meshes or primordial follicles. Where the egg clusters have not been completely shut in by bundles of connective tissue, the fusiform corpuscles of the latter may be distinctly followed up as far as the corpuscles of the germ epithelium, and, indeed, seem to disappear among them.

By the growth of the vascular tissue of the stroma among the imbedded corpuscles, the egg clusters in all parts of the ovary are gradually subdivided or broken up into single egg-containing meshes or follicles; and while this process is going on, the primordial ova are rapidly advancing in development. In the more superficial parts of the stroma subjacent to the egg clusters, and in the fibro-vascular zone of the ovary, the above-described process has already taken place. The primordial ova in some of the follicles are of very large size, and in the ovary of a four weeks' old kitten it is of great interest to compare the original germ epithelial corpuscles on the surface of the ovary with these large primordial ova now imbedded deep in the stroma, and we are thus able to observe what an extraordinary change has taken place in them during their development; and, what is of more importance, we recognise the nature of the change. Examined under a magnifying power of 1000 diameters, the ordinary germ epithelial corpuscle on the surface of the ovary appears as if it were of such a size that at least three of them would lie side by side on a threepenny piece without overlapping it; whereas the highly developed ovum imbedded deeply in

the stroma appears as large as a florin or a half-crown piece, and the nucleus or germinal vesicle as large as a threepenny or fourpenny piece. Between these two extremes young ova in all stages of development may be seen in the stroma of such a young ovary. The change which the germ epithelial corpuscle undergoes during its development is the following:—

As soon as the corpuscle is imbedded in the stroma, its nucleus swells up into a round or spherical body, within which generally appears a spot or nucleolus. The nucleus presents a sharply defined limiting membranous wall, and becomes the germinal vesicle of the future ovum. Immediately around the nucleus is gradually produced that protoplasm which afterwards constitutes the yelk of the mature egg. *In all parts of the ovary, wherever we examine such young developing ova, we find fusiform corpuscles, like the fusiform corpuscles of which the stroma is composed, lying in contact with the protoplasm which surrounds the nucleus or germinal vesicle.*

The youngest egg clusters are immediately below the germ epithelium, and many of them are in connection with it. These latter have not, as yet, been completely closed in and separated from the germ epithelial layer by the connective tissue bundles of the stroma.

The clusters of corpuscles in connection at their upper parts with the germ epithelium differ considerably from each other, both in size and form. Some are oval and elongated, others are spherical. Many of them are larger at their lower and middle parts than at the part in connection with the germ epithelial corpuscles. If a vertical section passes down through such clusters as these, such as are swollen out at their lower and middle parts but narrow at their upper parts, we have presented under the microscope the appearance as if bottle-shaped tubes full of round corpuscles extended from the germ epithelium downwards into the stroma of the ovary. These appearances are often seen, and it is important to study them well. It will be remembered that PFLÜGER* described in the young kitten's ovary numerous tubular processes passing downwards from the surface of the ovary into the stroma, in which the germinal vesicles originated, and by the successive divisions of which Graafian follicles containing eggs were formed. I have very carefully examined the ovaries of kittens and puppies, but have failed to find any tubular processes of epithelium passing into the stroma from which Graafian follicles are formed, and it appears to me that PFLÜGER is incorrect in stating that such exist in the ovary of the kitten.

In section, the ovary of a kitten at birth presents a structure very similar to that of the ovary of the two to three weeks' old kitten, but we find in the germ epithelium layer very few primordial ova. Many large spherical nuclei, with a thin film of protoplasm round them, are seen among the germ epithelial corpuscles, and

* PFLÜGER, "Die Eierstöcke der Saügethiere und des Menschen," Liepzig, 1863, p. 4.

the germ epithelial layer itself is much thicker as a stratum all round the ovary. Most of the large egg clusters below it, at this stage of development, are in communication superiorly with the corpuscles of the germ epithelium, and separating these clusters delicate bundles of young connective tissue, made up of minute fusiform corpuscles, may be traced growing up between and around them. In the deeper part or fibro-vascular zone of such a young ovary the stroma is rich in blood-vessels, and numerous young eggs are imbedded in its meshes, but no large eggs, such as we described in the four weeks' old kitten, are found.

The Human Ovary.

In section, the ovary of a human fœtus of about seven months presents a somewhat triangular form (fig. 7) The ovary (*a*) is attached to a stalk or peduncle (*b*) consisting of fibro-vascular tissue, which passes into the ovary at the hilum (*c*), and from the direct prolongations of which the whole stroma is derived. On examining a thin section of such an ovary under low powers of the microscope, direct prolongations from the stalk are seen proceeding in a radiating manner towards the periphery in all directions, and communicating with each other in such a manner that the whole stroma becomes arranged in the form of a mesh-work consisting of fibro-vascular tissue. In the meshes of this stroma are large and small collections of corpuscles. At the periphery of the organ the meshes are large, and the contained groups of corpuscles are correspondingly large; but as we pass deeper into the ovary the meshes with the included groups of corpuscles become smaller, till at last we find small meshes containing but one or two large corpuscles.

The surface of such an ovary is very irregular, presenting numerous small fossæ-like grooves and furrows, seen clearly under a low magnifying power.

Investing the ovary, and passing round it from one lateral border to the other, is a layer of columnar corpuscles. This layer is the germ epithelium (*h*, *h*), and as it invests the ovary it dips down into and lines certain tubular structures and tubiform depressions which, when seen in section, appear as passing down from the germ epithelial layer into the substance of the ovary.

(*a*). *Nature of the Germ Epithelium.*—In a fœtus of 7½ months the germ epithelium consists of columnar-shaped corpuscles placed side by side and arranged as an investment to the whole ovary.

The germ epithelial layer rests on a thin irregular stratum of connective tissue which is part of the general stroma of the ovary, and is formed by delicate processes of the same, which at an earlier stage of development grew upwards from the deeper parts of the ovary to surround and inclose in meshes those large groups of corpuscles found immediately under the germ epithelium in its entire extent. This young connective tissue stratum is the forerunner of the tunica albuginea.

On tearing to pieces in a little water a fragment of this ovary and examining the debris under high powers of the microscope, many small portions of the germ epithelium will be found. When the deep surface of the epithelial layer is examined, the corpuscles are seen to be placed close together, and present in the membrane a tessellated appearance (fig. 10). The chief part of each corpuscle is the nucleus. Around each nucleus is a small quantity of protoplasm which acts as a cement substance holding the nuclei together. When the germ epithelial membrane is looked down upon from above, immediately on bringing the corpuscles into view a clear space is seen round the nucleus of each corpuscle (figs. 11 and 12, *h*, *h*). This space is occupied by clear protoplasm. The corpuscles in this early stage of development appear as little nucleated pieces of protoplasm; the nucleus is always the conspicuous part of each corpuscle, but the protoplasm round it may vary in quantity. In each piece of epithelial membrane examined, the corpuscles are of different sizes. Some of the nuclei are swollen up into large spherical bodies (fig. 12, *l*), and around them is an increased quantity of clear protoplasm. In the larger nuclei a nucleolus is generally seen. The largest corpuscles are undoubtedly primordial ova. Between these and the smallest germ epithelial corpuscles every variety in size is met with.

When seen in profile (figs. 13, 14, 15, *h*, *h*, *h*), the germ epithelial corpuscles are columnar, but many of them are assuming an oval and spherical form (figs. 13, 14, 15, *l*, *l*, *l*). In the spherical ones the nucleus is clearly defined, and shows distinctly its well-marked membranous wall. Within the nucleus is a nucleolus, and around it is a thin film of protoplasm. In some instances this film is so fine as scarcely to be made out. When a section of a 7½ months' fœtal ovary is examined under high powers of the microscope, in many situations among the ordinary germ epithelial corpuscles all round the ovary, we find individuals standing forth prominently and conspicuous by their size and the size of their nuclei (figs. 14, 15, *m*, *m*) similar to those bodies we described as conspicuous among the corpuscles of the germ epithelium in the kitten's ovary. Such have been termed primordial ova. On comparing these with the smaller round corpuscles, and these latter with the ordinary germ epithelial corpuscles, it is easy to see that they are germ epithelial corpuscles in a far advanced stage of development. In the progress of growth the nucleus of the ordinary germ epithelial corpuscle first swells out and enlarges, becoming oval, then spherical, and around it is gradually produced that protoplasm which assumes such dimensions in the primordial ova. In contact with these primordial ova we often see small fusiform corpuscles (*n*, *n*), and as in the case of the kitten's ovary, some of them appear to have grown up among the germ epithelial corpuscles from the stratum of young connective tissue (*j*,*j*) on which the germ epithelium rests.

It is a fact of great interest, that as the germ epithelial corpuscle becomes a

primordial ovum, the nucleus, which at first appears ill-defined and semi-solid, and is surrounded by a comparatively small quantity of protoplasm, now shows a remarkably clear definition, and at last appears as a spherical vesicular body with a fine double-contoured wall, and within it one or two nucleoli are usually seen. The nucleus of each germ epithelial corpuscle becomes the germinal vesicle of the primordial ovum, and the nucleolus corresponds to the germinal spot.

The ordinary germ epithelial corpuscles measure in their longest diameter about $\frac{1}{1800}$th of an inch, and in their shortest about $\frac{1}{3600}$th of an inch, but both these measurements vary considerably.

On referring to WALDEYER's work "Eierstock und Ei," plate ii. figs. 9, 11, 13, I find that he represents the germ epithelial corpuscles as little bodies in which the nuclei are comparatively small, while the protoplasm round these is in all cases very extensive. This is not in accordance with my observations. An examination of the ovaries of numerous fœtal and newly-born animals clearly shows that in each ordinary germ epithelial corpuscle the nucleus constitutes by far the greater part of the corpuscle, the protoplasm around it being in the form of a fine film. In the primordial ova, however, the enlarged nucleus has around it a correspondingly large quantity of protoplasm, and then these bodies present the appearance as described by WALDEYER.

(*b.*) *The Relation of the Germ Epithelium to the Peritoneal Epithelium.*—In a section of the ovary of a $7\frac{1}{2}$ months' fœtus, the stalk or peduncle (fig. 8, *b*) is directly continued into the ovary to form the stroma, which we described as arranged in the form of a mesh-work. If we now direct our attention to the epithelium covering this stalk (fig. 9, *f*), we find it is directly continuous with the peritoneal epithelium, and on the other hand passes without a break into the epithelium which covers the ovary, but a gradual change in its character takes place as it slides into and becomes continuous with the latter.

In the peritoneal epithelium (fig. 9, *f*), as seen in profile, the nuclei of the cells are oval and flattened from above downwards, and are placed at a considerable distance from each other, and the protoplasm around them is extensive. Tracing this epithelium towards the ovary, as we approach the latter, we observe the nuclei of the epithelial cells to become round and columnar, and gradually to lie closer together until at last they are almost in contact. They then crowd together, and in the form of a thick layer pass on to the surface of the ovary as the corpuscles of the germ epithelium (*h*). As the corpuscles of the peritoneal epithelium gradually slide into those of the germ epithelium, we find the protoplasm which invests the nuclei of the former gradually becomes less and less in quantity, and the nuclei themselves become gradually larger and more columnar, until at last the nuclei pass on to the surface of the ovary as distinct columnar bodies, each having round it a fine investment of protoplasm. In thus tracing the peritoneal epithelial corpuscles into

germ epithelial corpuscles we see the nuclei undergoing fission, and by this process crowds of germ corpuscles are produced. The whole germ epithelial layer must be regarded as a thick layer of proliferating corpuscles. From the first appearance of the ovary as an organ until its development is completed, there is a constant proliferation of the germ epithelial corpuscles; and, in growth of the ovary, as fast as some corpuscles become imbedded in the stroma, others are produced to take their place.

It is interesting to recall to recollection the statements of SCHENK*, WALDEYER, and others, that in the first instance the whole peritoneal cavity is lined by a layer of columnar corpuscles, and when the Wolffian body appears in connection with REMAK'S middle plate, it likewise has an investment of similar corpuscles. The first appearance of the ovary is the thickening of this columnar epithelium on the median side of the Wolffian body (WALDEYER.) At the commencement of this thickening there is seen under it a small outgrowth of young connective tissue, continuous with and proceeding from the interstitial tissue of the Wolffian body. There can be little doubt that the thickening of the columnar epithelium is brought about by a proliferation of its corpuscles, and the proliferation itself is due to the influence on the corpuscles of the vascular young connective tissue subjacent to them. While the columnar corpuscles constantly proliferate to form the germ epithelial corpuscles, from which all the future ova are derived, the rest of the peritoneal chamber becomes lined by a layer of flat epithelium, forming the peritoneal epithelium.

From the very first appearance of the germ epithelium of the ovary as a distinct structure, processes of the subjacent young connective tissue grow upwards among the corpuscles as the first step in that process of imbedding, whereby the corpuscles become surrounded in meshes of vascular stroma, and ultimately form ova. From its earliest condition till late in the development of the ovary, the germ epithelium cannot be stripped off as a layer from the ovary, because delicate processes of the ovarian stroma are constantly growing up between the corpuscles as fast as they are produced.

PFLÜGER states his opinion that the ovum is simply a peritoneal epithelial cell. With this statement I cannot altogether agree. Both the ova and the peritoneal cells are undoubtedly evolved from a common ancestral source—the columnar layer of the great peritoneal cavity; but whilst in one limited region the columnar corpuscles form the germ epithelium and become converted into ova, in the greater part of their distribution they become converted into the endothelium lining the peritoneal cavity. Hence the ovum is no more a modified peritoneal epithelial cell than is the peritoneal epithelial cell a modified ovum.

From the corpuscles of the germ epithelium all the ova are derived. We

* Beiträge Zur Lehre von den Organ-Anlagen im motorischen Keimblatt.

recognise the germ epithelium by the fact that immediately below it all round the ovary are clusters or groups of corpuscles contained in meshes of the ovarian stroma, but under the peritoneal epithelium covering the stalk no such groups are found.

It is worthy of remark, however, that sometimes under those epithelial corpuscles, which, as it were, form a connecting link between peritoneal and germ epithelial corpuscles, we find small groups of round corpuscles apparently consisting of abortive ova. It is only under and in connection with the true germ epithelium that groups of true primordial ova are formed.

(*c.*) *The manner of Inclusion of the Primordial Ova and Germ Epithelial Corpuscles in the Stroma of the Ovary.*—In a section of the ovary of a human fœtus of 3½ months, one sees large strings of connective tissue corpuscles (fig. 19, *j,j,j*) growing upwards in a radiating manner from the deeper parts of the ovary toward the germ epithelium (*h, h.*) These strings or bundles communicate with each other and form meshes, and in these meshes are round groups of corpuscles (*o,o,o*) which resemble very closely the corpuscles of the germ epithelium (*h, h*) which invests the ovary. Immediately under the germ epithelium such groups of corpuscles may be seen partially imbedded in meshes of the stroma. In the deeper parts of the ovary we find large primordial ova (fig. 20, *m,m*) lying separate from each other, and in contact with the protoplasm which surrounds the germinal vesicle of each are small connective tissue corpuscles (*n, n*) exactly similar to those which make up the strings or bundles of young tissue in other parts of the ovary. These little connective tissue corpuscles are quite different in appearance from the corpuscles of the germ epithelium on the surface of this young ovary, or those imbedded in groups in the stroma.

The stroma of the human fœtal ovary of 7½ months consists almost entirely of fusiform connective tissue corpuscles, and in a section of such an ovary we find the whole stroma arranged in the form of a mesh-work, in the meshes of which are large and small groups of corpuscles, just as we described in the case of the ovary of the calf, the kitten, and human fœtal ovary of 3½ months. In the bundles of connective tissue corpuscles which (as seen in section) lie between the groups of corpuscles we find blood-vessels, and on close examination it is seen that the walls of such blood-vessels consist of connective tissue corpuscles. Wherever the bundles of connective tissue proceed, in the midst of them are blood-vessels. On tracing the bundles of vascular tissue upwards, we find they arch round large and small groups of corpuscles immediately under the germ epithelium, and completely inclose them in meshes. In some situations under the epithelium the connective tissue bundles have not yet grown round the groups of corpuscles, but may be traced up as far as the germ epithelial corpuscles on either side of the groups. Under the germ epithelial layer the youngest connective tissue is found, and in this situation it

is the forerunner of the tunica albuginea. This youngest connective tissue appears as a transparent jelly-like substance, and in it are numerous fusiform corpuscles or nuclei. Fine homogeneous points of this young tissue may be seen insinuating themselves among the corpuscles of the germ epithelium, and in some preparations of 6 and 7½ months' fœtal ovaries in which the germ epithelial layer is partially detached such fine points of the jelly-like young tissue may be seen in considerable numbers.

In many places immediately under the germ epithelium, small groups, consisting of a few germ epithelial corpuscles (fig. 21, *q, q, q*), are found in the act of being surrounded by this same jelly-like tissue; some of the groups are completely surrounded and separated from the germ epithelium layer, while others are partially surrounded, and are still in connection with the germ epithelium superiorly. The youngest connective tissue can always be traced in direct continuity with vascular bundles of tissue which completely surround the large groups of imbedded germ epithelial corpuscles, and is part of the general stroma of the ovary. This imbedding of germ epithelial corpuscles takes place under the germ epithelium all round the ovary.

After being thus included in meshes of the stroma, the germ epithelial corpuscles increase in number and in size, and there results the formation of those large egg clusters which are found under the germ epithelium in all parts of the ovary.

Each imbedded corpuscle undergoes the following change:—The nucleus enlarges, gradually becoming a spherical vesicular body, and the protoplasm which surrounds it is at the same time increased in quantity. As the result of the enlargement of each corpuscle in the group, the whole group as a cluster expands and becomes more or less spherical. As these egg clusters expand, those lying immediately under the germ epithelium push the latter structure before them, and in this manner the surface of the young ovary is made to present a very irregular appearance. Between the prominences or irregularities thus produced are depressions or furrows. These originate as simple depressions between two or more adjacent expanding egg clusters, and they become deepened by the growth and expansion of new egg clusters under the germ epithelium in connection with those already formed.

In describing the appearance of a seven and a half months' human fœtal ovary in section, I stated that the germ epithelium passed round the ovary from one lateral border to the other, dipping into and lining certain tube-like structures and tubiform depressions which appear to pass from the surface downwards into the organ. Now, if vertical sections are made through a young ovary such as above described, whose surface presents numerous irregularities, we have the appearance presented as if tube-like structures (fig. 22, *p, p*) passed down from the surface of the ovary into the substance of the organ, and

these are all lined by germ epithelium. Similar tube-like structures are produced when sections are made through the convoluted surface of a brain, and the grey matter might even be compared to the germ epithelium, inasmuch as it lines these sulci. But such structures are not tubes, nor are the similar appearances seen between the irregularities of the surface of a young fœtal ovary.

An examination of the young ovary, looking down on its surface from above, soon convinces us that there are no real tubular structures passing from the epithelium into the organ. On bringing the germ epithelium into view, and then slightly depressing the tube of the microscope, one sees large and small round groups of spherical corpuscles separated from each other by the connective tissue of the stroma, as was described by WALDEYER. Some of these groups are still in communication with the germ epithelial corpuscles, as may be seen in vertical sections where the knife has passed through a group of corpuscles not yet completely included in a mesh of the upward growing stroma.

In the germ epithelial layer which dips down into and lines the depressions of the surface of the ovary (fig. 22, *p*, *p*), we find the corpuscles undergoing changes during their development similar to the changes which the corpuscles of the germ epithelium in other situations undergo. At the bottom and sides of the sulci, among the corpuscles of the germ epithelium, we find large spherical nuclei with a thin investment of protoplasm, and large primordial ova, such as may be found in all parts of the germ epithelial layer, whether it lines depressions or passes over prominences of the surface of the ovary.

Frequently large egg clusters are formed under the germ epithelium which lines the furrows or sulci, and it often happens that the walls of these furrows come in contact; pushed together, as it were, by laterally situated expanding egg clusters. At the bottom of the furrows, where the epithelial walls come in contact, connective tissue passes through among the corpuscles, and in this way large egg clusters become formed immediately below the germ epithelium at the bottom of the sulci. A vertical section passing down through such a sulcus and the group of corpuscles immediately below it, produces the appearance as if a tubular prolongation of germ epithelium was dilated at its lower part into a large sac, full of developing corpuscles of the germ epithelium.

During my investigations on the structure of the ovary and development of the ova, I have never found any real tubular structures, neither in the human ovary, nor in any other mammal that I have examined, such as the cat, dog, calf, sheep, guinea-pig, rabbit, and in no instance have I found Graafian follicles formed out of such structures in the manner described by PFLÜGER, VALENTIN, SPIEGELBERG, WALDEYER, and others.

(*d.*) *Development of the Egg Clusters.*—Each egg cluster is a group or collection of germ epithelial corpuscles enclosed in a mesh or capsule of the ovarian stroma.

The germ epithelial corpuscles on the surface of the ovary constantly produce new elements by the process of fission, and when included in a vascular mesh of stroma the corpuscles increase greatly in number by division, and from a few imbedded corpuscles a large group or cluster may be derived. It appears to me a most interesting and remarkable observation that these corpuscles, after a certain increase in number, expand or swell out into spherical bodies, and a careful examination of the egg clusters has convinced me that this change is brought about by the nucleus in each corpuscle swelling out into a spherical vesicular body, which afterwards becomes the germinal vesicle of the primordial ovum, and in close contact with the wall of the nucleus is gradually produced that protoplasm which afterwards forms the yelk of the ovum.

In each egg cluster we find certain individuals much farther advanced in development than the rest, and these appear exactly like the large primordial ova which we described as found among the corpuscles of the germ epithelium on the surface of the ovary. Each corpuscle in the cluster is potentially a primordial ovum. At the first there is but a small quantity of protoplasm round the nuclei of the corpuscles in each egg cluster, but as the nuclei enlarge and expand, the protoplasm round them is gradually produced in considerable quantity.

This development of the germ epithelial corpuscles into primordial ova takes place in the egg clusters in all parts of the ovary. All the imbedded germ epithelial corpuscles do not reach the stage of primordial ova, many of them abort and disappear, and perhaps furnish a pabulum for the more vigorous and healthy ones.

In the ovary of a puppy at birth, one sees, in a beautiful manner, the egg clusters under the germ epithelium in all stages of development. Some of the clusters appear to consist entirely of large primordial ova, while in others we can trace the growth of the germ epithelial corpuscles into ova, and immediately under the germ epithelium are little groups of corpuscles in the act of being included in meshes of the stroma.

In following the further development of the ovary and ova, we notice that around each egg cluster is a well-marked capsule or mesh of vascular connective tissue. This connective tissue consists almost entirely of fusiform corpuscles and young blood-vessels. Just as at first, when delicate processes of the young stroma grew upwards among the ordinary germ epithelial corpuscles to include them in meshes, so now delicate processes of the young connective tissue with blood-vessels proceed from the walls of these meshes, and insinuate themselves in among the developing corpuscles in each egg cluster. As these processes thicken, the primordial ova gradually become separated from each other, and at last each is included in its own mesh or capsule of the stroma.

These single egg-containing meshes or capsules are the primordial follicles.

This formation of young Graafian follicles takes place in the egg clusters in all parts of the ovary, and at the same time new egg clusters are being formed under the germ epithelium in the manner described. In the ovary of a 7½ months' human fœtus we find many newly-formed egg clusters immediately under the germ epithelium, but below these, earlier formed egg clusters are in various stages of alteration into single egg-containing follicles, while deeper still we find a great number of young follicles all produced from the first formed clusters in the way we have described (fig. 24).

In the first formed Graafian follicles, which are situated most deeply in the stroma of the ovary, the young ova are of large size, and we are at once struck by the fact that the germinal vesicles in all are about the same size, although the protoplasm around them may vary considerably in quantity.

In each young Graafian follicle the ovum fits tightly; it occupies the whole cavity of the follicle; there is no space between it and the wall (fig. 24, *m*, *m*, *m*). The mesh of stroma closely embraces the protoplasm of the ovum, and in almost every case we find fusiform connective tissue corpuscles (*n*, *n*) in the wall of the mesh lying in close contact with and indenting the yelk of the young ovum. Wherever we examine the primordial follicles, we see such fusiform corpuscles of the stroma lying in contact with and indenting the yelk of the contained ova. I called attention to the circumstance that among the germ epithelial corpuscles on the surface of the ovary primordial ova were found, having in contact with their protoplasm small fusiform corpuscles, which in some instances could be traced growing as offshoots from delicate bundles of similar bodies which formed part of the ovarian stroma.

(*e.*) *The Development of the Membrana Granulosa.*—The stroma of the human fœtal ovary is remarkable for the great number of connective tissue corpuscles it contains. Wherever we examine the stroma and its processes in all parts of the ovary, we find in it well-formed connective tissue corpuscles. In the middle parts of the ovary, where the stroma is well developed, the connective tissue corpuscles show very distinctly a central oval nucleus with nucleolus. Around the nucleus is a small quantity of protoplasm, drawn out at either end in a fusiform manner. Besides these we see naked nuclei and many small round bodies; in these latter the nucleus is in a state of division into two or more parts. These small round bodies appear to be swollen out connective tissue corpuscles. In a well-formed connective tissue corpuscle the nucleus is comparable to the germinal vesicle of the ovum, and like it, at a certain stage of its development, it shows a sharply-defined double contoured wall. In all parts of the ovary we find the connective tissue corpuscles dividing.

In various parts of the stroma we find delicate fibres developing into connective tissue corpuscles. The central part of such fibres becomes swollen out, and in this swollen out part a distinct oval nucleus appears; sometimes

these fibres are direct prolongations of the protoplasm surrounding the nuclei of well-formed connective tissue corpuscles. The nucleus of a connective tissue corpuscle at first often appears as a solid or semisolid body, but it may become distinctly vesicular, like the nucleus or germinal vesicle of the ovum.

It will be observed that, in my description of the germ epithelium and of the development of the ova, I have avoided the use of the word cell, and substituted the term corpuscle, and my reason for not using the term cell in connection with the germ epithelial corpuscles is, that the germ epithelial corpuscles, and the so-called columnar epithelial cells which line the pleuro-peritoneal cavity of the embryo, are nuclei which have a thin film or investment of protoplasm round them. These nuclei are the homologues of the nuclei of the peritoneal epithelial cells. When a corpuscle divides, each half of the nucleus carries with it a small investment of protoplasm. The protoplasm round the nuclei varies considerably in quantity during the development of the germ epithelial corpuscle. The term cell is employed in somewhat different significations by biologists. Some, for example, holding that a cell must have a definite wall, whilst others look upon the wall as of secondary and minor importance, and hold that a cell essentially consists of a nucleated mass of protoplasm. The germ epithelial corpuscles and connective tissue corpuscles do not possess a cell wall. When once a cell wall has formed round a corpuscle, the nucleus and cell contents may divide. The cell wall does not participate in the division, but incloses the products of the division. The cell wall may burst and liberate the contents of the cell.

Every egg cluster is included in a mesh of the stroma. This mesh consists of connective tissue corpuscles and minute blood-vessels whose walls consist of such corpuscles. Delicate processes of this vascular young tissue from the wall of the mesh grow inwards among the corpuscles which are developing into primordial ova. On tearing to pieces small fragments of a 7½ months' fœtal ovary, and placing the debris in a little water under the microsrope, we find small groups of primordial ova (figs. 25, 26), and single individuals (figs. 27, 28, 29), which have been torn away from the egg cluster, and in connection with some of the largest of these we frequently find fusiform corpuscles (figs. 28, 29, *n*, *n*) similar to those which lie in the walls of the meshes. In good specimens the fusiform corpuscles are found lying in indentations in the yelk substance (figs. 28, 29) which surrounds the germinal vesicle of the primordial ovum, and sometimes we see primordial ova whose yelk is indented in many places, but the fusiform corpuscles have been displaced from these indentations. No zona pellucida is found round such young primordial ova. The connective tissue corpuscles must therefore be in contact with the yelk of the primordial ova.

Directing our attention to the youngest follicles, we find these vary in size, but in every case the young ovum fills up the whole follicle in such a manner

that its protoplasm presses against and distends the follicular wall. Little fusiform corpuscles in the walls, *and belonging to the stroma of the ovary*, indent the protoplasm of each young ovum as it lies in its follicle. (Fig. 24, *m*, *m*.)

In an empty follicle from which the young ovum has been removed, these little connective tissue corpuscles appear as minute buds projecting into the cavity of the follicle from its wall.

In the deeper parts of the ovary numerous young egg-containing follicles are seen. In the youngest follicles but two or three fusiform corpuscles are found in contact with the yelk of the contained ovum. As the follicles increase in size and become older, the number of small corpuscles in contact with the contained ova also increases. In some we find seven or eight, and in still older follicles a perfect wreath of minute corpuscles is formed round the yelk of the young ovum. The oldest follicles are found in the deepest parts of the ovary, and in most of them there is a perfect wreath of minute corpuscles (fig. 30, *r*) lining the follicle. Now, from these young connective tissue corpuscles in the wall of the young follicles which lie in contact with and indent the yelk of the primordial ova, the corpuscles of the membrana granulosa are derived.

In describing the growth of fibre-like bodies in the stroma into connective tissue corpuscles, I stated that the middle parts of such fibres become swollen out, and in the swollen out part a distinct nucleus appears. This nucleus, though at first appearing semi-solid, may become distinctly vesicular, and within it a nucleolus is afterwards seen. By a careful examination of a whole series of young Graafian follicles, we trace the development of the corpuscles of the membrana granulosa in the following way:—Around the young ovum in each follicle the connective tissue corpuscles increase in number by division. As a single fusiform corpuscle divides, its nucleus appears to commence the division, and each half of the nucleus carries with it a small quantity of the protoplasm which originally invested the single nucleus. When a little wreath of such corpuscles is formed round the young ovum the nucleus of each corpuscle swells out and becomes a distinctly vesicular little body, presenting a very fine double contoured wall, around which is a small quantity of protoplasm. Within the nucleus generally a minute spot is seen. The protoplasm which surrounds the vesicular nuclei acts as a sort of cement substance, holding them together in the form of a capsular membrane round the young ovum. This capsular membrane is the first appearance of the membrana granulosa.

Only those connective tissue corpuscles which lie in actual contact with the yelk of the ovum in the follicle develope into corpuscles of the membrana granulosa; while those in the wall outside the membrana granulosa remain as connective tissue corpuscles, and follow the usual developmental process into ordinary fibrous tissue, of which the main part of the follicular wall at last consists. We shall afterwards see that in some of the oldest Graafian follicles in the adult

ovary, in man and other mammals, which are about to burst to liberate the contained ovum, a great part of the wall of the follicle outside the membrana granulosa becomes again converted into large connective tissue corpuscles.

When first formed, the membrana granulosa consists of a single layer of minute corpuscles arranged in the form of a capsule round the ovum (fig. 30, *r*). As the young ovum enlarges, which it rapidly does after the formation of the membrana granulosa, it distends its follicle, and the corpuscles of the membrana granulosa increase greatly in number. In this membrane, when first formed, the corpuscles lie in close contact with each other, and when looked down upon from above they present a polygonal form from mutual compression (fig. 32, *r*). By the constant multiplication by division of its corpuscles, the membrana granulosa at last comes to consist of several layers. As a further stage in development, certain of the corpuscles, generally those in the middle parts of the membrana granulosa, break down, and, it appears to me, become dissolved in a fluid which afterwards forms the liquor folliculi. By the breaking down and solution of these corpuscles, a cavity, the follicular space occupied by fluid, is formed. In section, this space appears semilunar in form. After the formation of this space the ovum is not entirely separated from the membrana granulosa, but remains connected with the wall of the follicle by a heap of corpuscles which surrounds it. In good specimens a layer of corpuscles remains in contact with the zona pellucida round the ovum for a long time after the formation of the follicular space. When first formed, the corpuscles of the membrana granulosa in the human fœtal ovary of 7½ months measure about $\frac{1}{3000}$th inch.

For the complete demonstration of the development of the corpuscles of the membrana granulosa, the ovary of an adult rabbit is admirably suited. In a section of such an ovary, we first direct our attention to the structure of the stroma of the organ, and we find it consists entirely of very minute attenuated fusiform corpuscles. At first sight these appear as simple fibres, but each fibre is an elongated nucleus, having round it a minute quantity of protoplasm. The stroma of the ovary of an adult cat has an exactly similar structure. In the adult rabbit's ovary, in a single section, we may find young ova in various stages of development. In a very young ovum (fig. 33, *m*), we notice first the large germinal vesicle, with its germinal spot. Around the germinal vesicle is a small quantity of protoplasm, immediately in contact with which are several small fusiform corpuscles (*n*, *n*). These lie flattened against the ovum round its yelk, and are exactly similar to fusiform corpuscles, of which the stroma (*j*) is composed. Around an ovum slightly farther advanced in growth we find one or two of the fusiform corpuscles (*n*, *n*) have assumed a swollen condition, and in some instances individual corpuscles are in the act of dividing. In the case of an ovum still farther advanced in develop-

ment, the corpuscles round the yelk substance have now assumed a spherical form, and as they increase in number and press against each other, they gradually become columnar (fig. 35, *r*).

As in the case of the human fœtal ovary of 7½ months, the corpuscles of the membrana granulosa thus formed consist of vesicular nuclei placed close together, their walls being almost in contact, but a very minute quantity of cement material lying between them. When this young membrana granulosa is looked down upon from above, the corpuscles present a beautiful pavemented appearance. The nucleus of each corpuscle is polygonal from pressure by its neighbours (fig. 36, *r*). By the constant division of the corpuscles, the membrana granulosa soon consists of several layers (fig. 37, *r*), and a follicular space is formed by the breaking down and solution of some of the corpuscles. In the nearly ripe Graafian follicle of the rabbit's ovary one frequently finds several small follicular spaces in different parts of the thick membrana granulosa; and in a section made through such a follicle, bands or straps of membrana granulosa cells appear to pass from the ovum to the wall of the follicle. These bands were called "Retinacula" by MARTIN BARRY. They are simply appearances produced when the section has passed through the walls or septa which separate several follicular spaces lying near each other.

In the ovary of the adult or old cat (fig. 39), we can trace in a beautiful manner the growth of the corpuscles of the membrana granulosa from the fusiform corpuscles of the stroma, which lie next to the protoplasm or yelk of the imbedded young eggs. In a section, we have first the epithelium on the surface. This consists of small flat polygonal nucleated cells (fig. 40, h_1), about $\frac{1}{2000}$th or $\frac{1}{2500}$th part of an inch in diameter. This layer of epithelium is all that remains of the germ epithelium, and it can be stripped off from the ovary without difficulty. Below the epithelium, and passing round the ovary, is a stratum of connective tissue, consisting of elongated fusiform corpuscles. In the lower part of this stratum the fibres decussate freely. Immediately below this layer we come upon the remains of the large egg clusters which we described in the young kitten's ovary. A perfect zone, consisting of young eggs, lies immediately under the stratum of tissue which passes horizontally round the ovary, under the epithelium. In this zone the eggs lie very close together, many of them are in actual contact. In each egg we recognise the central germinal vesicle, with its spot or nucleolus—the germinal vesicles are all about the same size. Below this zone of eggs is the general stroma of the ovary, processes of which consisting of elongated fusiform corpuscles and fibres, grow in between and around all the eggs in the egg zone. These processes of stroma then become continuous with the horizontal zone of tissue which lies external to the egg zone, and with it grow round the ovary to form the tunica albuginea. As the processes of the stroma of the ovary grow in between and around the young eggs in the egg

zone, fusiform connective tissue corpuscles (*n*, *n*) may be seen lying in contact with the yelk substance of the eggs, and these fusiform corpuscles are exactly similar in appearance to the corpuscles which make up the stroma (*j*, *j*) in other parts of the ovary. Around many of the young eggs the corpuscles of the membrana granulosa may be traced as they develope from these fusiform connective tissue corpuscles. The nuclei of these connective tissue corpuscles divide, swell up, and gradually form a wreath of little nuclei round the ovum. Each little vesicular nucleus has around it a small quantity of protoplasm, and in the nucleus a spot is generally found. By a constant division of these corpuscles the membrana granulosa at last consists of a thick layer, just as in the case of the Graafian follicle in the rabbit's ovary.

In the adult human ovary an exactly similar development of membrana granulosa corpuscles can be followed out. As the eggs lie imbedded in the stroma, the nuclei of those elongated fibres of the stroma which are in contact with the yelk substance swell up, and by constant division produce a wreath of little corpuscles round the ovum.

On comparing the epithelium on the surface of these adult ovaries with the fusiform corpuscles which lie round the young eggs imbedded in the stroma of the ovary, from which the corpuscles of the membrana granulosa are produced, we at once see how altogether different they are in appearance, and how impossible it is that there can be any connection between them. The epithelium on the surface of the adult cat's ovary is separated from the deeply imbedded eggs by a thick layer of connective tissue, and while the corpuscles of the epithelium are flat, polygonal bodies, with oval nuclei, the corpuscles in contact with the imbedded young eggs are elongated fusiform bodies, similar to those which make up the stroma in all parts of the ovary. By carefully examining these fusiform bodies as they lie on the surface of the egg, and as they lie round the egg, as in a profile view, it is seen that they are entirely different from the epithelial corpuscles on the surface of the ovary, and they are parts of the ovarian stroma. These observations appear to me to prove very conclusively that WALDEYER's view as to the development of the cells of the membrana granulosa is untenable.

After a single layer of membrana granulosa corpuscles is produced round the ovum, the wall of the follicle outside this capsular layer becomes fibrous and vascular. The wall of a nearly ripe Graafian follicle is very vascular. In the rabbit's ovary, in a very young follicle, the corpuscles around the egg, which give rise to the membrana granulosa corpuscles, are at first minute fusiform bodies, and lie flattened against the ovum, when seen in profile. As they develope into the corpuscles of the membrana granulosa they swell up, and by pressure against each other become columnar. Now, immediately outside this layer of columnar corpuscles the tissue consists of minute fusiform corpuscles (figs. 35, 36, 37, *j*,

j, j) and blood-vessels. In a nearly ripe Graafian follicle, just before bursting to liberate the ovum, these minute corpuscles in the wall of the follicle outside the membrana granulosa swell up and enlarge, producing large fusiform corpuscles (fig. 38, *j, j*) very similar to the corpuscles of the membrana granulosa at a certain stage of development. This condition of the wall of the ripe follicle is also well seen in the human ovary. In the wall of the nearly ripe Graafian follicle of the rabbit's ovary, we can trace these large fusiform corpuscles becoming more and more like the ordinary small corpuscles of the stroma, as we examine them in the more external parts of the follicular wall. I have ascertained by careful observation that from the very first appearance of the Graafian follicles to their bursting, no blood-vessels pass into the cavity of the follicle to reach the ovum, and yet this body increases enormously in size in a short space of time. This great increase in size is brought about by the production of protoplasm or yelk round the germinal vesicle, even after the latter has reached a definite size.

The chief function of the membrana granulosa is to nourish the ovum during its development. From the first appearance of the ovum as an ordinary germ epithelial corpuscle, until the development of the embryo and its extrusion from the uterus, it exists as a parasite. On the surface of the ovary at first it is an ordinary germ epithelial corpuscle. In the ovary, during a certain stage of its development, it is simply surrounded by vascular nutritious tissue, of which, however, it forms no part, but is simply resting on it. Here it imbibes nourishment until it is thrown off from the ovary. It then passes into the uterus, where changes due to impregnation occur in it, and processes of its surface become imbedded in the vascular mucous membrane of the uterus, and by the agency of these nourishment is absorbed for the germ till it reaches a certain stage of development, when it is thrown off from the parent. In the uterus, as in the ovary, the ovum is simply surrounded by vascular nutritious tissue of which it forms no part, but simply rests on it, and absorbs nourishment from it for its own development.

In the old follicles, some of the cells of the membrana granulosa show a distinct but fine cell-wall round the protoplasm which invests the nucleus. In some of my preparations of the rabbit's ovary, the division of the nuclei of the corpuscles in the membrana granulosa is excellently seen (fig. 31, *v*.) In these older follicles the protoplasm round the nucleus of the membrana granulosa corpuscle is sometimes very extensive, forming a thick layer which may be found drawn out in a fusiform manner (fig. 38, *u*) at one or more points.

In certain parts of the adult cat's and rabbit's ovary, we find large patches of granular cells, and running in between the cells are processes of connective tissue. These large granular cells have nuclei, but they are indistinctly seen because of the granular nature of the substance which surrounds them. In most cases the

nuclei appear as round or oval bodies with nucleoli. An examination of the patches shows that the granular cells are swollen up individuals of the membrana granulosa from old and probably ruptured follicles, and are undergoing a fatty degeneration, while at the same time connective tissue corpuscles from the wall of the follicle are growing in between them. In almost every old ovary we find large yellow patches, consisting of the cells we have now described.

At birth the stroma of the human ovary is well developed in every part, and is arranged in a perfect network throughout the whole organ. The ovary might be compared to a piece of sponge in whose meshes ova are contained. The ova in the human ovary at birth are very numerous. They may be fairly estimated at about 35,000 in each organ. In favourable specimens a section of such an ovary presents under the microscope a splendid object. In it the stroma appears to be actually saturated with young ova (fig. 23, *m*), in all of which we can recognise the germinal vesicle as a distinct spherical body, and sometimes two or more germinal spots are seen in it, and around each germinal vesicle is the yelk substance filling up the entire cavity of the Graafian follicle. In all parts of the stroma the minute connective tissue corpuscles crowd together, and in the deeper parts of the ovary, where the oldest Graafian follicles are situated, the connective tissue corpuscles in the walls of the follicles may be seen in contact with and indenting the yelk substance of the included young ova, and in these cases the development of the corpuscles of the membrana granulosa may be clearly followed out. In such a section, under the germ epithelium, the last formed egg clusters have not as yet been completely subdivided by the connective tissue stroma into the ultimate egg containing meshes or Graafian follicles, but this is rapidly approaching completion.

After birth, the inclusion of germ epithelial corpuscles by the ovarian stroma becomes less and less, until at the age of about two years the process has entirely ceased; for at this period of development the tunica albuginea has assumed a special character as a complete investment to the whole ovary under the germ epithelium. Most superficially its fibres are arranged in a stratified manner, and run horizontally round the organ; and in sections the general stroma of the ovary is seen in connection with the tunica albuginea in all parts.

From the earliest appearance of the ovary we have on the one hand a growth of germ epithelial corpuscles, and on the other a growth of vascular connective tissue. The germ epithelial corpuscles, in groups or clusters, become gradually surrounded by the vascular connective tissue, and, as development proceeds, the connective tissue grows into the groups between the corpuscles, and these become at last separated from each other, and by the thickening of the tissue in, between, and around them, they are ultimately included in separate

meshes of the stroma. At the same time the imbedded corpuscles are developing into primordial ova. This intercorpuscular growth of connective tissue takes place in all parts of the ovary wherever groups of germ epithelial corpuscles become imbedded, and it continues until the inclusion of germ epithelial corpuscles from the surface of the ovary has ceased. It is in this way, and in this way only, that we have Graafian follicles formed. As already explained, the Graafian follicles are the ultimate meshes of the stroma, formed by the growth of the connective tissue around the developing primordial ova. As these young ova become surrounded by the vascular tissue, the connective tissue corpuscles in the wall of the follicles in contact with their yelk develope into the corpuscles of the membrana granulosa in the manner described. According to my observations, tubular structures have no existence in the ovary at any period of its development, and I have never detected the formation of Graafian follicles and the corpuscles of the membrana granulosa in any other manner than that I have indicated.

By the continued free growth of the vascular stroma throughout the whole organ, the walls of the Graafian follicles become greatly thickened. The oldest and largest Graafian follicles are situated in the deepest parts of the stroma; this is what we would naturally expect, for they were the first formed, and lie surrounded by a great number of blood-vessels which are branches of the large trunks entering the ovary at the hilum.

Thus, in the ovary of a rabbit of about six weeks, one sees the largest Graafian follicle situated deeply in the organ; on the surface of the ovary is the germ epithelium. Between the deeply situated Graafian follicles and the germ epithelium on the surface of the ovary, the Graafian follicles with the contained ova become gradually less and less in size. The youngest Graafian follicles, the last formed, are found immediately under the layer of tissue known as the tunica albuginea on which the germ epithelium rests.

Although the eggs are so numerous in an ovary at birth, very few of them come to maturity.

In the ovary of a cat about five months old is a thick zone of young eggs immediately under that stratum of tissue which passes round the ovary constituting the tunica albuginea. This egg zone is all that remains of the egg clusters which I described as forming so large a part of the ovary of a kitten of two to four weeks.

Below the egg zone the ovary consists of fibro-vascular tissue. This part forms about two-thirds of the whole organ, and thick processes of it pass upwards among the eggs in the egg zone. These thick processes have developed from the long strings or delicate bundles of fusiform corpuscles, which in the young kitten grew up between the egg clusters separating these latter from each other. Secondary offshoots may now be traced growing from the larger bundles in

between the eggs, and as these processes thicken all traces of single large egg clusters become obliterated, and a complete zone of eggs, passing round the ovary takes their place. In this egg zone a great number of eggs become destroyed. In some cases large vacuoles form in the yelk or protoplasm which surrounds the germinal vesicle, and this latter structure is often pushed aside or pressed against the wall of the follicle. The germinal vesicle itself does not seem to be involved in this process of vacuolation. The vacuoles form in the yelk and not in the germinal vesicle. In the human ovary at birth I have also seen a large number of eggs distorted or destroyed by the formation of large vacuoles in the yelk substance.

I do not attempt to explain the meaning of this formation of vacuoles in the yelk substance of the young eggs. I have observed it in the ovaries of several mammals, and I have also seen it taking place in the protoplasm which surrounds the nuclei of large cancer cells, obtained from cancerous ovaries and other malignant growths. I may also mention, that I have seen vacuoles in the protoplasm around the nuclei of pus and renal epithelial cells.

In the central part of this five months' cat's ovary large Graafian follicles are found in various stages of development.

In the growth of these large Graafian follicles, many young and smaller follicles are destroyed by pressure; and it would appear that many of the imbedded eggs simply atrophy and form a pabulum for the connective tissue corpuscles which surround them.

It may be asked, What becomes of the germ epithelium after its egg-forming character has disappeared?

After birth the corpuscles of the germ epithelium gradually become smaller in size, losing their columnar form, till at the age of six years, in the case of the human ovary, they present the appearance of small flattened corpuscles (fig. 41, h_1). They are very small, measuring in their longest diameter not more than the $\frac{1}{3000}$th part of an inch. The epithelial membrane composed of such corpuscles can be stripped off the surface of the ovary without difficulty. In the human ovary at twelve years of age, the epithelium has preserved an almost identical appearance to that above described, the epithelial corpuscles still remaining of very small size. In the ovary of an adult, the epithelial corpuscles do not measure more than the $\frac{1}{3000}$th to the $\frac{1}{2500}$th part of an inch in diameter.

In the ovary of old rabbits, the germ epithelial corpuscles remain as a well-marked layer of small oval corpuscles, and in the ovary of old cats the corpuscles are flattened from above downwards, and show very beautifully their epithelial character (fig. 40, h_1). The corpuscles show well-marked oval nuclei, and the protoplasm round them is extended out and abuts against the protoplasm around neighbouring nuclei; at the lines of contact there is the appearance of a cell wall.

Structure of the Ovum.

In man and in the cat the mature ovum measures about the $\frac{1}{180}$th part of an inch in diameter.

The zona pellucida, so named by Von Baer, appears when examined under low powers as a strong, perfectly transparent, homogeneous lamella sharply differentiated from the yelk. The membrane possesses considerable elasticity, and when torn to pieces with a needle, the yelk substance with the germinal vesicle escapes in a stream.

Generally, the external surface is exactly parallel to the internal, but in certain specimens I have seen fine processes of the membrane projecting outwards in a radiating manner between the epithelial corpuscles which invest the ovum.

In the zona pellucida investing the ovum in the rabbit's ovary, when examined under very high powers, fine radiating lines may be seen running through it from its external to its internal surface. I have not seen these lines in the zona pellucida in the cat. They were first described by J. Müller and Remak in the vitelline membrane of the ova of fish. In an extremely thin section of the zona in the rabbit's ovum I have not been able to see them, but in thick sections they are readily found. I believe these radiated lines do not indicate any special structure of the zona, but are produced by the membrana granulosa cells which lie in contact with each other, the lines of contact being seen through the zona as fine linear marks.

The zona resists the action of acetic acid, and its chemical characters are not accurately known.

It is extremely difficult to say how the zona is formed. By most continental observers it is considered to be a product of the follicular epithelium, but from the circumstance that in many instances in the cat's ovary I have discovered it as a well-marked structure round the ovum when little or no trace of the follicular epithelium existed, I am inclined to the belief that it is formed by a hardening of the external part of the yelk of the ovum. I regard the ovum as a large cell, of which the zona is the cell wall and the germinal vesicle is the nucleus.

The parts of the ovum within the zona pellucida consist of the yelk substance and the germinal vesicle. The yelk substance forms by far the greater part of the mature ovum, and constitutes a large spherical mass in which a number of minute granules are suspended. In the eggs of young cats these granules and small bright bodies are found collected together at the external part of the yelk near the zona pellucida. As already mentioned, the primordial eggs do not possess a cell wall at first, but lie in the young Graafian follicles with their yelk substance in close contact with the fibrous wall of the stroma which

surrounds them. It is not uncommon to find two primordial ova in a single Graafian follicle, and as these eggs develope and lie in close contact with each other they are flattened one against the other, and a distinct zona pellucida may be seen round the yelk of each, although no follicular epithelial cells intervene between the eggs. Follicular epithelial cells, however, line the follicle in which these eggs are contained.

I have failed to detect any membrane between the yelk and the zona pellucida. In the mature eggs, as well as in the primordial ova, large vacuoles are occasionally found.

The germinal vesicle appears as a sharply defined globular body placed somewhat excentrically in the interior of the yelk, and is about a fifth to a sixth of the whole egg in diameter. It possesses a delicate membranous wall clearly defined under high powers of the microscope. The germinal vesicle is a highly refractile body, and is at once conspicuous within the ovum. Within it a few granules and one or two distinct nucleoli are found. In a human ovary at birth, very frequently primordial ova with two germinal vesicles are detected, and I have one specimen of the ovary of a child of two years in which a large single ovum contains four well-formed distinct germinal vesicles. In this case the yelk substance is very extensive, and completely surrounds the four vesicles. The wall of the Graafian follicle is in close contact with the yelk, and small fusiform corpuscles around this substance may be traced developing into the corpuscles of the membrana granulosa, but no zona pellucida is to be seen. In the ovary of an adult woman I have also seen a single ovum with two germinal vesicles, but the egg was comparatively young and no zona pellucida or complete epithelial investment was around it.

The nucleolus or macula germinativa is said to be always present in the primordial egg. The presence of two or three germinal spots in a single germinal vesicle has often been noted. Besides the germinal spot a few minute corpuscles are occasionally seen in the germinal vesicle. By some the germinal spot is thought to be a solid body, and by others it is considered to be of the nature of a vesicle, and I have seen round it an extremely fine linear investment. In the cat's ovum very frequently a minute bright spot or vacuole is noticed in the germinal spot. SCHRÖN described this as a solid body, and termed it the "granule." (KORN).

GENERAL CONCLUSIONS.

The following general conclusions have been arrived at in the course of my investigations:—

The corpuscles of the germ epithelium are derived by direct proliferation from those columnar corpuscles which invest the median side or surface of the Wolffian body, and which are continuous with the layer of columnar corpuscles

that lines the pleuro-peritoneal cavity of the embryo in the early stages of development. The stroma of the ovary in the early stages of development is produced by a direct growth out from the interstitial tissue of the Wolffian body immediately beneath the germ epithelium on the median side of the Wolffian body.

The germ epithelial corpuscles proliferate by fission. In the human fœtal ovary of $7\frac{1}{2}$ months they measure $\frac{1}{2500}$th to $\frac{1}{2000}$th of an inch in their longest diameter, and about $\frac{1}{3500}$th of an inch in their shortest diameter. Each germ epithelial corpuscle is a nucleus surrounded by a thin film or investment of clear protoplasm. In the act of becoming primordial ova, the nucleus of each germ epithelial corpuscle swells up into a spherical body, within which is generally seen a nucleolus, and around which is produced clear homogeneous protoplasm which subsequently forms the yelk of the ovum. Germ epithelial corpuscles are seen on the surface of the ovary in all stages of development into primordial ova. In each primordial ovum the spherical germinal vesicle presents a sharply defined limiting membranous wall. Within the germinal vesicle is the nucleolus or germinal spot. All the ova in the ovary are derived from germ epithelial corpuscles.

In all parts of the germ epithelium processes of vascular connective tissue stroma grow in between and around certain of the germ epithelial corpuscles, whereby the latter become more and more imbedded in the stroma of the ovary. Germ epithelial corpuscles are being constantly produced on the surface of the ovary, to take the place of those already imbedded in the stroma. The imbedded corpuscles increase in number by division, and the nucleus of each swells up into a spherical germinal vesicle, around which is gradually produced the yelk of the ovum. In all parts of the young ovary under the germ epithelium, groups of germ epithelial corpuscles become imbedded in meshes of the stroma. As each individual in the group swells up the nucleus or germinal vesicle becomes very distinct as a round or spherical body. From the swelling out of each germ epithelial corpuscle in the group, the whole group expands and becomes more or less spherical. Such groups of developing corpuscles are called egg clusters. Each egg cluster is inclosed is a mesh or capsule of vascular stroma of the ovary. Each imbedded germ epithelial corpuscle is potentially an ovum.

The stroma of the young ovary consists for the most part of fusiform connective tissue corpuscles and blood-vessels. The walls of the young blood-vessels in the young stroma consist of connective tissue corpuscles. The connective tissue corpuscles are direct offshoots from the ovarian stroma, and are found in contact with the yelk or protoplasm of each primordial ovum situated among the germ epithelial corpuscles on the surface of the ovary. Wherever we find primordial ova we see connective tissue corpuscles in con-

tact with the yelk of each. In all parts of the ovary we find the nuclei of connective tissue corpuscles dividing. Sometimes these corpuscles are swollen out into round bodies containing three to four nuclei. In each egg cluster several of the included germ epithelial corpuscles are in a much farther advanced stage of development than their fellows. From the walls of the meshes inclosing the egg clusters, delicate processes of vascular connective tissue grow in, between, and around individual corpuscles in the egg clusters, and by a continued intergrowth of the young stroma in this manner each individual of the group becomes at last enclosed in a separate mesh or capsule. These last formed meshes are the Graafian follicles.

As a rule, each Graafian follicle is occupied by one young ovum. The protoplasm or yelk of each ovum is in close contact with the wall of each Graafian follicle. In contact with the yelk of each young ovum, and indenting it, are connective tissue corpuscles, which form part of the wall of each Graafian follicle. In the formation of the membrana granulosa, these connective tissue corpuscles in the wall of the Graafian follicle, and in contact with the yelk of the contained ovum, increase in number by division, their nuclei swell out into little vesicles, and at last a perfect capsule of such corpuscles is produced round the ovum. This capsule is the membrana granulosa or follicular epithelium of the follicle. At first the membrana granulosa consists of a simple layer of corpuscles lining the follicle. The individual corpuscles of the membrana granulosa in the human ovary measure about $\frac{1}{3000}$th inch. As the ovum becomes mature, the corpuscles of the membrana granulosa proliferate, and then many layers of small corpuscles are produced between the ovum and the follicular wall. The cells of the membrana granulosa are thus derived from the corpuscles of the connective tissue stroma, and not, as WALDEYER states, from the germ epithelial corpuscles. The follicular space is formed by a breaking down and probable solution of certain of the corpuscles of the thickened follicular epithelium in the middle parts of the same. The discus proligerus consists of follicular epithelial corpuscles, which are in contact with the zona pellucida of the ovum. The zona pellucida or vitelline membrane is formed by a hardening of the outer part of the yelk or protoplasm of the ovum, and is not, as REICHERT, PFLÜGER, and WALDEYER stated, a product of the follicular epithelium. At birth the human ovary contains not less than 35,000 ova, few of which reach maturity.

In the human ovary at birth the germinal vesicles measure $\frac{1}{1500}$th to $\frac{1}{1200}$th of an inch. Most of them are about the same size, and present a sharply-defined membranous wall. In some germinal vesicles two or three germinal spots are seen. The tunica albuginea is the thickened stroma growing round the ovary. At the age of $2\frac{1}{2}$ years all formation of ova from the germ epithelium has ceased.

Graafian follicles are not formed from tubular structures in the manner

described by PFLÜGER, SPIEGELBERG, and WALDEYER. The appearance of tubular structures passing into the stroma of the ovary are produced by sections through furrows and depressions between irregular prominences on the surface of the fœtal ovary. The irregularities of the surface of the fœtal ovary are produced at first by the expansion of egg clusters upwards under the germ epithelium. Where the walls of furrows and depressions come in contact, egg clusters are formed by the imbedding of germ epithelial corpuscles in that situation, just as in other situations. Egg clusters are formed in connection with the germ epithelium lining the furrows and depressions. Among the germ epithelial corpuscles lining the furrows, &c., we find large primordial ova, and corpuscles in all stages of development into the same, just as in other situations among the ordinary germ epithelial corpuscles.

In the human fœtus, round and oval-shaped groups of germ epithelial corpuscles are found in connection with the germ epithelium all round the ovary. When vertical sections are made through these they present the appearance as if tubular structures filled with developing germ epithelial corpuscles passed from the germ epithelium downwards into the stroma of the ovary.

The development of the corpuscles of the membrana granulosa, from connective tissue corpuscles of the stroma, can be well followed out in the ovaries of adult rabbits and cats.

At the age of six years the epithelium on the human ovary consists of very small flat hexagonal-shaped corpuscles, measuring $\frac{1}{2500}$th to $\frac{1}{3200}$th of an inch. The corpuscles are undergoing division. This layer can be stripped offwithout difficulty. At the age of twelve the epithelium has little difference in appearance from the above, the small size of the epithelial corpuscles being remarkable. The epithelium is beautifully seen in old cats, and must be regarded as homologous with the peritoneal epithelium. In old cats the epithelium on the surface of the ovary consists of very small distinct cells, measuring from $\frac{1}{1800}$th to $\frac{1}{2000}$th inch, with granular oval nuclei.

EXPLANATION OF PLATES.

In these plates the same letters have been employed to mark corresponding structures in the whole series of figures.

a. The parenchyma of the ovary.
b. The fibro-vascular peduncle or stalk of the ovary.
c. The lower border of the ovary at the hilum.
d. The layer of epithelium on the stalk of the ovary.
e. The layer of epithelium stripped off from the stalk, and seen from a surface view.
f. Peritoneal epithelial corpuscles.
g. Corpuscles intermediate between peritoneal and germ epithelial corpuscles.
h. Germ epithelial corpuscles.
h_1. Corpuscles from the surface of adult ovary.
i. Fusiform shaped corpuscles among germ epithelial corpuscles.
j. Connective-tissue stroma of the ovary.
k. Blood-vessels.
l. Large spherical germ epithelial corpuscles.
m. Primordial ova.
n. Fusiform corpuscles in contact with the yelk-substance of the primordial ova.
o. Large egg clusters.
p. Tubiform depressions of the surface of the ovary.
q. Small groups of germ epithelial corpuscles being included in the stroma of the ovary.
r. The membrana granulosa.
s. The zona pellucida.
t. The yelk substance of the nearly mature ovum.
u. Individual corpuscles of the membrana granulosa, showing the nucleus surrounded with a considerable quantity of protoplasm.
v. Division of the nuclei of the corpuscles of the membrana granulosa.

PLATE XXVII.

Figure 1. Vertical section through the ovary of a fœtal calf, about 9 inches long, showing the parenchyma (*a*) and the fibro-vascular stalk or peduncle (*b*) prolonged into the ovary at the hilum (*c*). On the surface of the peduncle is a layer of epithelium (*d*). (Page 349.)

Figure 2. Surface view of this layer of epithelium. (Page 349.)

Figure 3. Profile view of the same layer of epithelium, showing the gradual change of peritoneal epithelial corpuscles (*f*) into germ epithelial corpuscles (*h*). (Page 350.)

Figure 4. The parenchyma of the fœtal calf's ovary, showing the germ epithelial corpuscles (*h*) and the growth of delicate connective-tissue of the stroma (*j*) and blood-vessels (*k*) among the corpuscles below the germ epithelium. (Page 350.)

Figure 5. A portion of the fibro-vascular zone of the fœtal calf's ovary, showing a primordial ovum (*m*), surrounded with a wreath of small corpuscles, outside of which are blood-vessels (*k*) and young connective-tissue. (Page 351.)

Figure 6. Portion of the ovary of a kitten about three weeks old, showing the germ epithelium (*h*), large spherical germ epithelial corpuscles (*l*), and primordial ova (*m*.) In contact with the yelk substance of these primordial ova are fusiform corpuscles (*n*). Bundles of young connective-tissue (*j*) are seen growing upwards, between, and around large egg clusters (*o*), situated immediately below the germ epithelium. (Page 352.)

Figure 7. Semidiagrammatic drawing of the ovary of a human fœtus of 7½ months, showing the parenchyma (*a*), and the fibro-vascular peduncle (*b*), prolonged into the ovary at the hilum (*c*). From the peduncle the whole stroma of the ovary is derived. The germ epithelium (*h*) rests on the youngest connective-tissue, which is part of the stroma, and is the forerunner of the tunica albugineæ. (Page 357.)

PLATE XXVIII.

Figure 8. Section of a human fœtal ovary of 7½ months, seen under a low magnifying power, showing the stalk or peduncle (*b*), the parenchyma of the ovary (*a*), and the lower border of the ovary (*c*).

Figure 9. A portion of the same ovary highly magnified showing the gradual change of peritoneal epithelial corpuscles (*f*) on the peduncle into germ epithelial corpuscles (*h*) at the lower border of the ovary (*c*). (Page 359.)

Figures 10, 11, 12. Surface view of the germ epithelium from the same ovary. In figure 12, among the ordinary germ epithelial corpuscles (*h*) large spherical germ epithelial corpuscles (*l*) are seen. (Page 358.)

Figure 13. The ordinary germ epithelial corpuscle (*h*) and the larger spherical corpuscle (*l*). (Page 358.)

Figures 14, 15, 16. Profile views of the germ epithelium. Among the ordinary columnar corpuscles (*h*) large spherical corpuscles (*l*) and primordial ova (*m*) are seen. Fusiform corpuscles (*n*) are in contact with the yelk of the primordial ova. (Page 358.)

Figure 17. A large primordial ovum (*m*), with several large spherical corpuscles (*l*) included in a mesh of the stroma (*j*) under the germ epithelium (*h*).

Figure 18. An egg cluster (*o*), consisting of large sperical corpuscles (*l*) included in a mesh of the stroma (*j*), under the germ epithelium (*h*).

Plate XXIX.

Figure 19. A portion of the ovary of a human fœtus of 3½ months, showing the germ epitheljum (*h*) and groups of large germ epithelial corpuscles or egg clusters (*o*) imbedded in the stroma. The stroma (*j*) consists almost entirely of connective-tissue corpuscles. (Page 361.)

Figure 20. A portion of the same ovary, showing large primordial ova (*m*) imbedded in the stroma (*j*). Fusiform corpuscles (*n*) of the stroma are seen in contact with the yelk of these primordial ova. (Page 361.)

Figure 21. A portion of the ovary of a human fœtus of 7½ months, showing the manner of inclusion of the germ epithelial corpuscles in groups (*q*) in the stroma of the ovary. (Page 362.)

Figure 22. A portion of the ovary of a human fœtus of 7½ months, showing in section the furrows (*p*) which lie between the prominences on the surface of the ovary. (Page 363.)

Figure 23. A portion of the ovary of a child at birth, showing the stroma (*j*) crowded with primordial ova (*m*).

Plate XXX.

Figure 24. Section through the ovary of a human fœtus of 7½ months, showing the germ epithelium (*h*), large spherical corpuscles (*l*), and groups of similar corpuscles or egg clusters (*o*) imbedded in meshes of the stroma (*j*). In the lower part of the figure many primordial ova (*m*) in various stages of development are seen. In contact with each primordial ovum are fusiform, connective-tissue corpuscles (*n*), similar to the fusiform corpuscles of which the stroma consists. Numerous blood-vessels (*k*), whose walls consist of connective-tissue corpuscles, ramify throughout the whole ovary. (Page 365.)

Figure 25. A small egg cluster consisting of large spherical germ epithelial corpuscles with fusiform connective tissue corpuscles (*n*) intermingled. (Page 366.)

Figure 26. A small group of spherical germ epithelial corpuscles.

Figure 27. A primordial ovum. It has no zona pellucida.

Figures 28, 29. Primordial ova (*m*). In contact with and indenting the yelk substance of each, are fusiform connective-tissue corpuscles from the wall of the young Graafian follicle.

Figure 30. The membrana granulosa (*r*) when first formed seen in section. Outside the membrana is the ovarian stroma (*j*). From the human ovary at birth.

Figure 31. The corpuscles of the membrana granulosa from the nearly ripe Graafian follicle of the rabbit's ovary. The letter *v* points to the division of the nuclei of the corpuscles.

Figure 32. Surface view of the membrana granulosa (*r*) when first formed. From the human ovary at birth.

Plate XXXI.

Figures, 33, 34, 35 36, 37, 38, illustrate the development of the membrana granulosa in the ovary of an adult rabbit. (Page 368.)

Figure 33. A primordial ovum (*m*). Fusiform connective-tissue corpuscles (*n*) of the stroma (*j*) lie in contact with the yelk substance of the young ovum.

Figure 34. A young ovum farther advanced in development than the last. Some of the fusiform corpuscles (*n*) in contact with the yelk are swollen out.

Figure 35. An ovum still farther advanced in development, completely surrounded by a wreath of corpuscles, which have been derived from the fusiform corpuscles of the stroma (j). This wreath is the membrana granulosa (r) seen in section.

Figure 36. A Graafian follicle from which the ovum has been removed. The membrana granulosa (r) is seen in section.

Figure 37. A section through a Graafian follicle, and the nearly ripe ovum contained in it. The membrana granulosa (r) consists of several layers of corpuscles. The zona pellucida (s) is well developed, and the yelk substance (t) at its peripheral part contains numerous bright granules and particles.

Figure 38. A section through the membrana granulosa and wall of a ripe Graafian follicle just before bursting. The membrana granulosa (r) consists of several layers of corpuscles. Each corpuscle is a large nucleus surrounded by protoplasm (u). In the wall of the follicle outside the membrana granulosa the fusiform corpuscles of the stroma (j) are very large. (Page 371.)

Figure 39. A section through the egg zone of an old cat's ovary. The stroma (j) consists almost entirely of fusiform corpuscles. Around the young eggs (m) the fusiform corpuscles (n) of the stroma may be traced in their development into the corpuscles of the membrana granulosa. (Page 369.)

Figure 40. The epithelium (h_1) from the surface of the same cat's ovary.

Figure 41. The epithelium (h_1) from the surface of the ovary of a child six years of age.

Figure 42. The same epithelium more highly magnified showing the "grooved" appearance of the corpuscles.

Figure 43. Germ epithelial corpuscles (h) seen in profile. From the ovary of a $7\frac{1}{2}$ months' human fœtus.

Figure 44. A primordial ovum (m) surrounded with fusiform corpuscles (n). From the stroma of the same ovary.

Figure 45. An ovum (t) from the deeper parts of the same ovary, showing the appearance of the membrana granulosa (r) when first formed round the ovum.

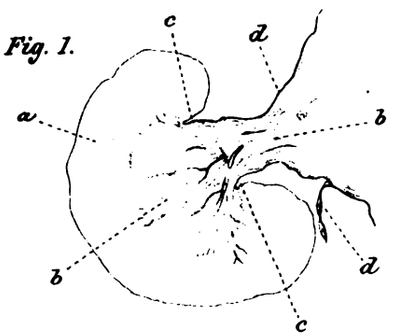
Fig. 1.
c
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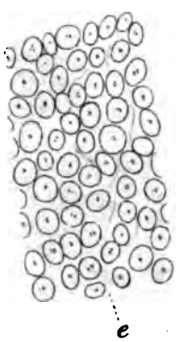
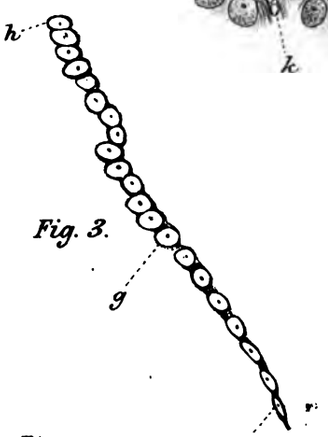


Fig. 2.
e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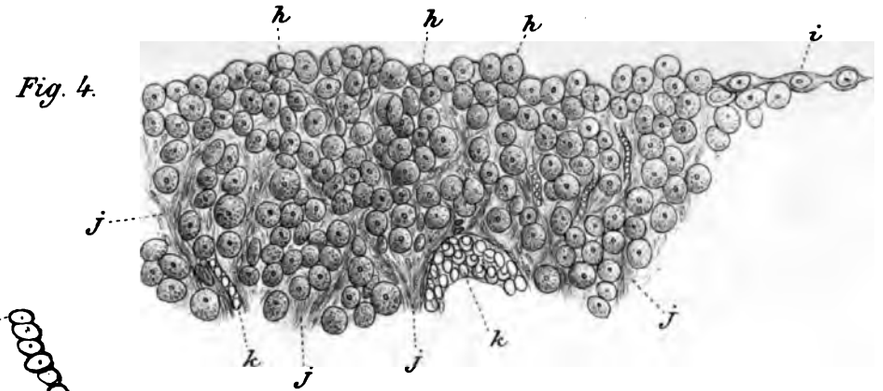
f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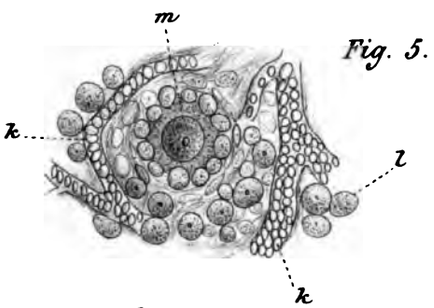
Fig. 5.
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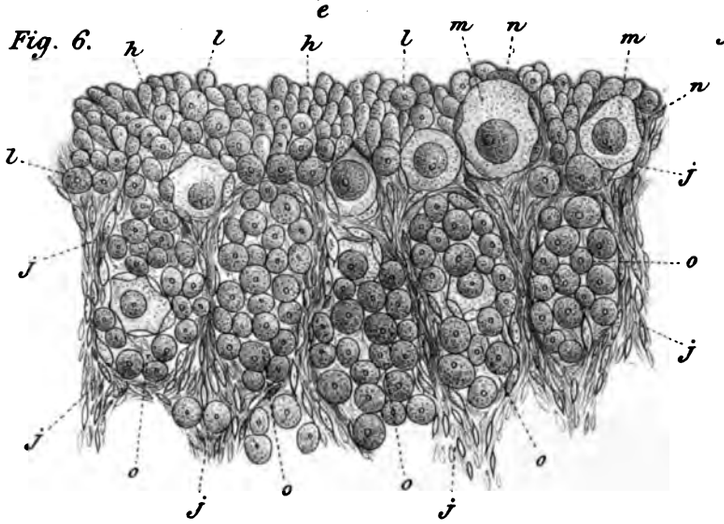
Fig. 6.
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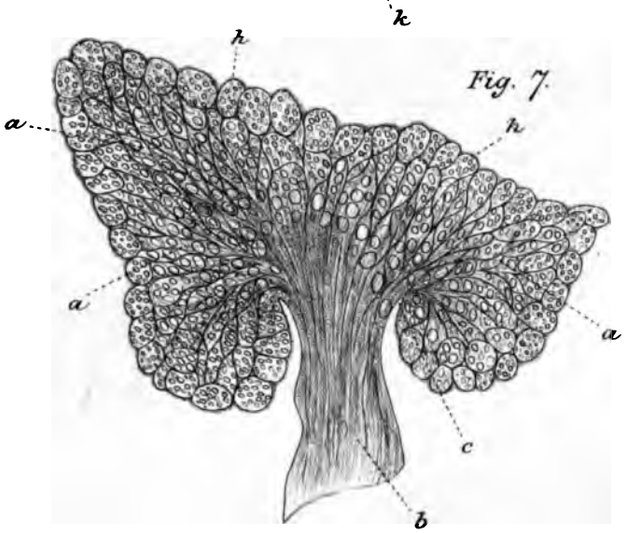
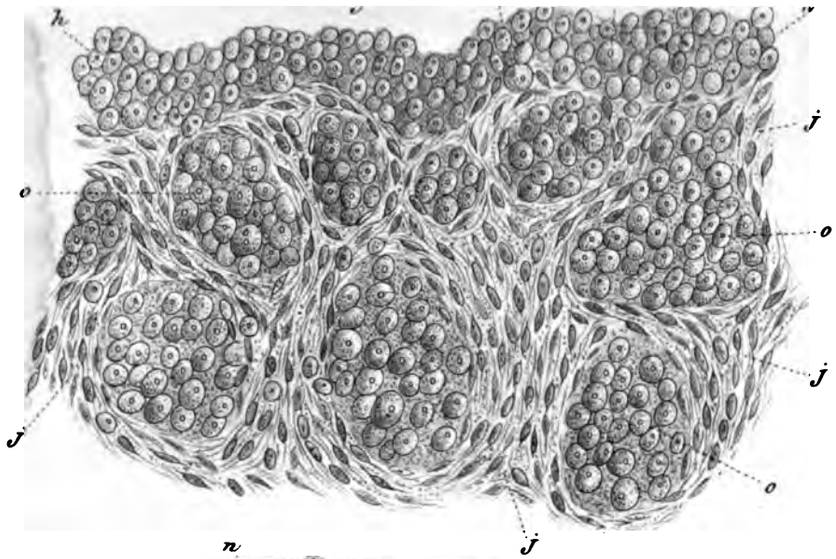


Fig. 7.
h
a
h
a
a
c
b

Jas. Foulis, M.D. delt.

Mrs Farlane & Erskine, Lithrs Edinr.

UNIV. OF MICH.



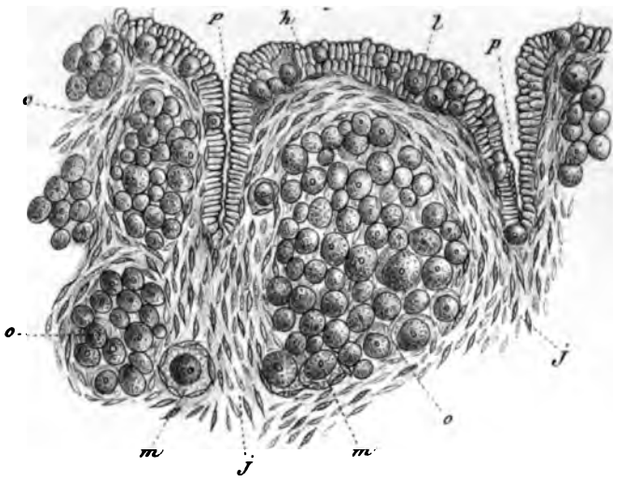


Fig. 20.

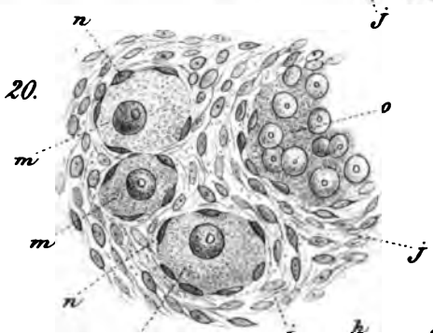


Fig. 21.

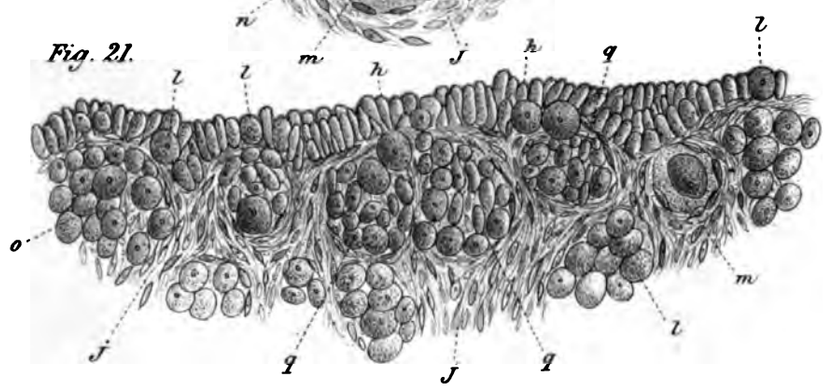
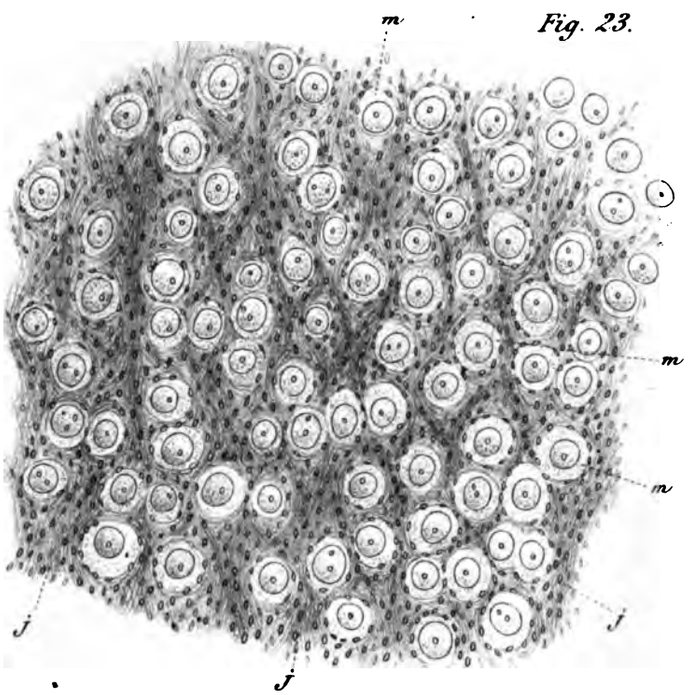


Fig. 23.



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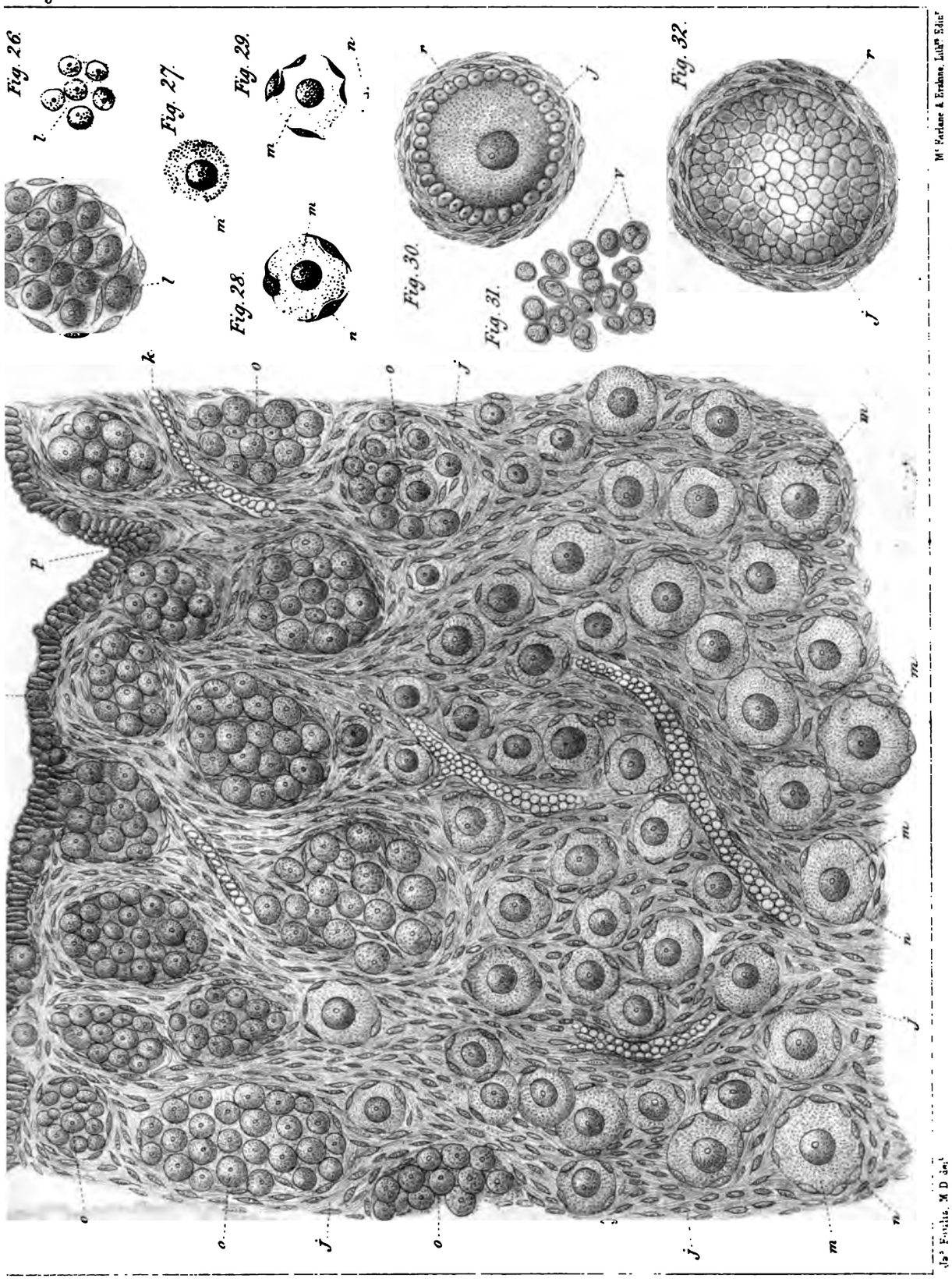
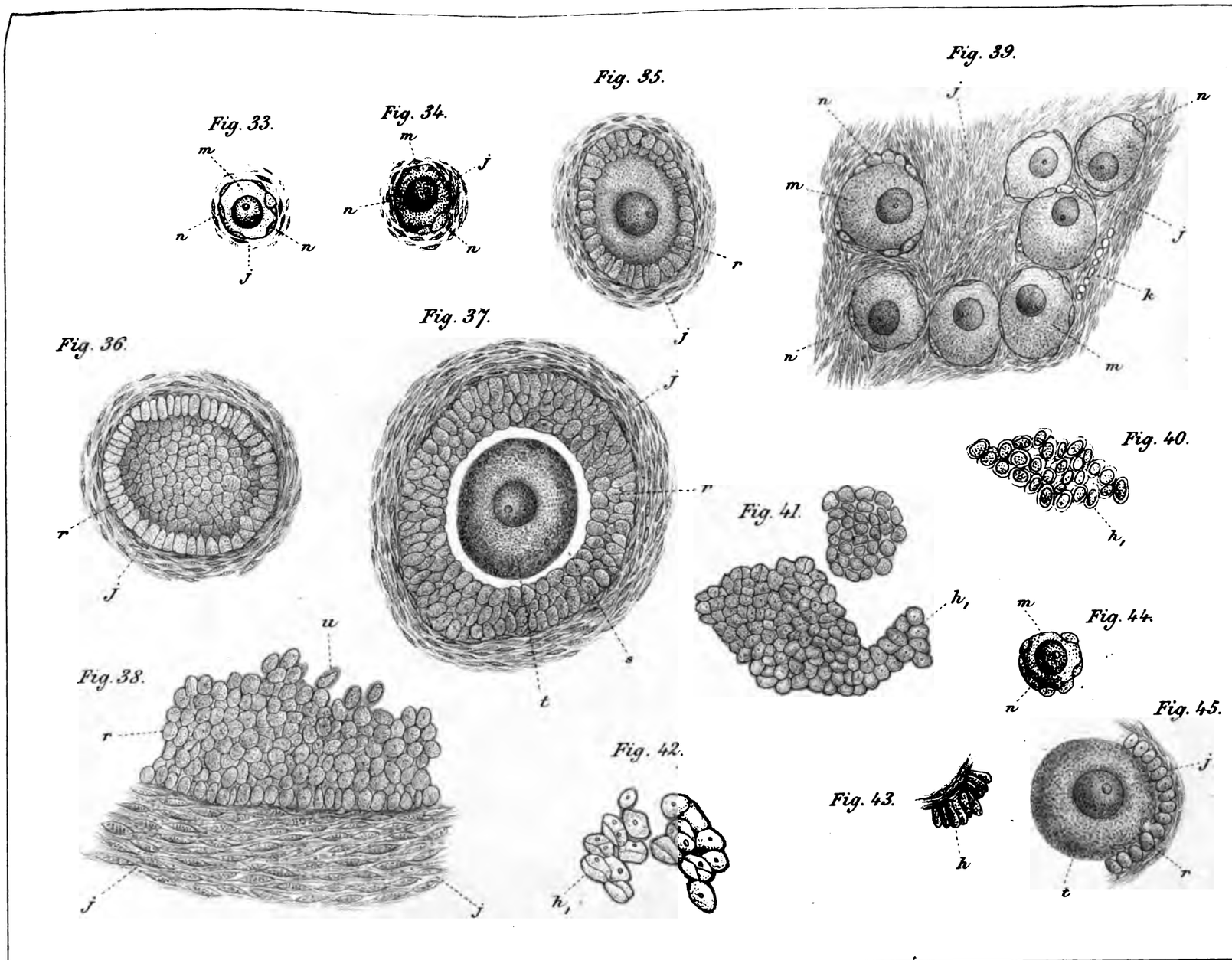


Mr Farlane & Erskine, Lith^rs Edin^r
Jas Fairlie, M.D. del^t



Jas Foulis, M D delt

Mc Farlane & Erskine, Lithrs Edinr

DISSERTATIO
MEDICA INAUGURALIS,
DE
CHOLERA INDICA.

Viro Ornatissimo
Jabez Hogg
Dat, Auctor
1862

HOC RECIPIT NEMO NISI DIGNUS

Disputatio Medica Inauguralis

DE CHOLERA EPIDEMICA INDIAE ORIENTALIS

QUAM

annuente summo numine

Ex Auctoritate Rectoris Magnifici

CORNELII JACOBI VAN ASSEN,

D. U. O. et Profess. Ordin.

NEC NON

Amplissimi Senatus Academici Consensu, et Nobilissimae Facultatis Medicae Decreto

PRO GRADU DOCTORATUS

Summisque in Medicina, Honoribus ac Privilegiis in Academia Lugduno Batava rite et legitime consequendis defendet

GEORGIUS WITT, Anglus.

Coll. Reg. Chir. Lond. Soc. et Nuper in Class. Indic. Orient. Chirurgus.

Ad Diem XII Junii MDCCCXXX, hora HI.

LUGDUNI BATAVORUM, apud C. C. van der HOEK, A°. 1830

ARCHIBALDO. ROBERTSON. M. D.
NOSOCOMII. NORTHAMPTONIENSIS
MEDICO. SENIORI
NON. MEDICINA. SOLVM
VERVM. ETIAM. OMNIGENA. DISCIPLINA
DOCTO
LITERISQVE. HVMANIORIBVS
ORNATO
GRATIAS. AGIT. MAXIMAS
PRO. BENEFICIIS. INNVMERIS
PROBISQVE. PRAECEPTIS
DE. STVDIO. MEDICINAE. INSTITVENDO
HAS. PRIMITIAS
PIGNVS. ANIMI. GRATISSIMI
SVMMA. CVM. OBSERVANTIA
DAT. DICAT. CONSECRATQVE
GEORGIVS. WITT

SAMVELI. SERLE
IN
CLASSE. INDICA. ORIENTALI
DVCI
PROPTER. COMITATEM. INSIGNEM
SVMMAMQVE. VITAE. INTEGRITATEM
HOC. OPVSCVLVM
LEVE. QVIDEM. AMICITIAE
AT. CORDIS. BENEFICIORVM. MEMORIS
VERAX. INDICIVM
SVMMAE. VOLVPTATIS. SENSV
DAT. DICATQVE
AVCTOR

» Multa in his rebus quaerantur, multaque nobis
» Clarandum est, plane si res exponere avemus.''

LUCRET. *de Rer. Natur.*
Lib. VI. *vs.* 778 *seq.*

DISSERTATIO MEDICA INAUGURALIS

DE

CHOLERA INDIAE ORIENTALIS EPIDEMICA.

PROOEMIUM.

Paucae sunt corporis humani affectiones, quae vel medicorum mentem ac solertiam magis excitaverunt, vel hominibus, inter quos grassabantur, majorem incusserunt terrorem, quam *Cholera Indiae Orientalis Epidemica.* Variae ac discrepantes medicorum diversis temporibus de isto morbo opiniones nimium probant, illos veram ejus naturam plane ignoravisse, ac relationes de summa ejus lethalitate non minus remediorum adhibitorum arguunt inefficaciam. Hinc quisque usu peritus, qui hujus morbi naturam qualitercunque describere posse sibi visus est, laboris sui fructus expomere se oportere existimavit.

Relationum de hoc malo scriptarum ingens copia, brevi temporis spatio, inde ab ortu ejus, ex India in Britanniam missa, haud

minus medicorum et chirurgorum, in illa terrarum parte artem salutarem factitantium, indefessum studium ac diligentiam, quam morbi, quem investigare atque explorare studebant, horrendam indolem testantur.

Multa igitur magni pretii scripta de illius historia et progressu nobis allata sunt; parum vero ad curationem efficacem instituendam eadem adhuc contulisse valde dolemus. Quamobrem etiamsi multum jam sit praestitum, multum adhuc agendum restat. Quod cum reputarem hoc potissimum argumentum elegi, quo legibus Belgicarum Academiarum satisfacerem, summos in medicina honores in celeberrima hac universarum doctrinarum palaestra consecuturus.

I.

MORBI HISTORIA.

Morbus jam describendus vulgo putatur apparuisse mense Augusto anni MDCCCXVII in *Jessore* (*) oppido centies fere mille passibus a *Calcutta* inter orientem et occidentem distante. Inde pagatim progre-

(*) Narravit mihi quidam militum dux, qui per XXVII annos in India versatus eladem hujus epidemiae non semel spectaverat, choleram, quamvis primum in *Jessore* a Chirurgis Europaeis observatam, multo ante comparuisse in celebri mercatu, qui quotannis habetur in urbe *Hurrdwarr*, juxta fines septentrionales Hindostani, quo omnes Orientis nationes immensa multitudine confluunt ibique per aliquot hebdomades commorantur.

gressus jam ineunte Septembri *Calcuttam* invasit, multaque hominum millia prostravit. Hinc ad oppidum *Behar* usque serpens complures urbes majores incolis fere spoliavit, adeo ut, qui vitam servare vellent, ad alia loca tutiora confugere cogerentur. Praecipua autem loca, quae succedente tempore ista calamitate plus minusve, affecti sunt, nominantur *Benares*, *Allahabad*, *Goruckpore*, *Lucknow*, *Cawnpore*, *Delhi*, *Agra*, *Muttra*, *Meerut* ac *Barcilly*.

Propagabatur scilicet iste morbus non simul ac semel, sed cursum suum pestiferum quasi per stationes conficiebat, et primo agmine prostrato invadebat alterum. Tandem exercitum magnum attingebat et per varias grassabatur ejus divisiones, quae apud *Mundellah*, *Jubbulpore* et *Saugor* morabantur, terribilem in modum regionem *Deccan* transiens. Apud *Hussingabad* horrendam per aliquot dies stragem edebat, ripas amnis *Nerbuddah* secutus vagabatur ad *Poonah* et juxta littus ad *Panwell* usque tendebat, ubi ad septentrionem ac meridiem conversus *Salsette* insulam transgrediebatur, atque ad *Bombay* perveniebat altera Septembris hebdomade anni MDCCCXVIII, anno scilicet vertente postquam *Calcuttae* exortus erat.

Quod quum contingeret in occidentali Peninsulae parte, Cholera eodem fere progressu orientales atque australes regiones versus procedebat, adeo ut per *Coromandelae* oram continuo se porrigeret, ipsamque insulam *Ceylanum* misere vastaret. Hinc magis magisque orientem petens, ingressa est epidemia plagas, quae puriore gaudent aëre ac sub temperatiore jacent coelo, ita ut et *Sianense* et *Chinense* regnum occuparet, per *Malaccam* peninsulam ad *Sumatram* perve-

ni-

niret ac tandem *Sundae* fretum permeans *Bataviam* invaderet. Inde ad Mauritii insulam perrexit, navesque tam in portubus ibi quiescentes, quam per mare Indicum dispersas, contagio infecit.

Per totam illam orbis terrarum partem furere dira illa epidemia non destitit, donec anno MDCCCXXI violentia ejus admodum decrescere inciperet. Fertur quidem morbus maximam partem mitioris jam esse naturae; at in nonnullis locis et occasionibus, haud secus ac antea saevire pergit.

Haec quam modo exhibui historiam de cursu ac progressione Cholerae sponte excitat quaestionem, num haec prima fuerit occasio, qua se in Hindostan manifestaverit? Quod affirmandum esse equidem haud putaverim; quamvis ex diligentissima amplissimaque investigatione ab Indicis aeque ac Europaeis scriptoribus instituta, nulla peti possint documenta, quae probent exstitisse aliquem morbum, cujus phaenomena cum Cholera ista aequiparari possint.

Choleram sporadica forma *Jac. Bontius* accurate descripsit, *Sonneratius* autem et *Bartholomaeus* leviore calamo. Sed hi auctores ad illam Cholerae formam, quae *biliosa* vocatur, rectius eam referre videntur. *Dellon* (*) tamen eam exposuit tamquam magis accedentem ad praesentis epidemiae indolem; imo ipsi audivimus ex documentis fide dignis, quae in Indica-Domo Londini asservantur, quum nuper relegerentur, cognitum esse, in *Bengalae* regno abhinc centum fere annis grassatum esse morbum, praesenti epidemiae non absimilem, adeo ut Delloni observatio, non multis annis prior, egregie confirmetur. Quam-

(*) Voyage aux Indes Orient. Amst. 1689.

Quamquam medicis anno MDCCCXXIV ex India referentibus Cholera remittere videretur, tertio tamen anno post, quum mihi praesentem morbum observare contingeret, in australi *Bengalae* parte cum Indigenas, tum Europaeos advenas terribili strage corripiebat; illorum tantus erat interitus, ut quinquaginta homines quovis die absumerentur in oppidulo *Ingelee*, ad ripam fluminis *Hoogly* sito; Europaei etiam, qui sive in littore erant, sive in navibus Anglicis, ad dicti fluminis ostia in anchoris stantibus, eadem adversitate premebantur.

Quum hic morbi impetus quoad causam esset memorabilis, et quoad effectus gravissimus, constitui succincta narratione morbum describere, qui duabus formis distinctis se exhibuit, subjuncta casuum obviorum eorumque exitus expositione cum aegrorum numero.

II.

MORBI DESCRIPTIO.

Cholera quum sit recentior morbus, saltem quantum memoriae proditum est, ex priscis scriptoribus adaequata ejus definitio haud peti potest. Id, quod Doct. *Cullen* de illa docet, certe referendum est ad eam formam, quae cum aucta secretione et fluxu bilis flavae conjuncta est, atque ad veterem Choleram morbum, quem non adeo gravem habuisse videtur, ita ut non nisi blande diluentia remedia praebenda esse jusserit. Similiter *Sauvages* omnes Cholerae

species morbos non adeo graves duxisse videtur, quamvis *Dellonem* secutus Cholerae Indicae mentionem faciat, et in curatione a sanguinis missione abstinendum, sed leniter purgantia adhibenda esse censeat. Nonnunquam tamen tam exitiosam Cholerae morbi indolem dicit, ut non parvi momenti habenda sit. Quod et antiquissimis temporibus medici peritissimi agnoverunt. *Hippocrates* (*), qui passim hujus morbi mentionem facit, de Atheniensi quodam casum refert, cujus symptomata fuerint satis violentia. Alii quoque Graeci auctores Choleram memorant; his vero praetermissis non possum non proferre accuratam *Celsi* descriptionem (**): De intestinorum morbis dicturus, » primo," inquit, » facienda mentio est *cholerae;* » quia commune id stomachi atque intestinorum vitium videri po» test. Nam simul et dejectio et vomitus est: praeterque haec inflatio » est, intestina torquentur, bilis supra infraque erumpit, primum » aquae similis, deinde ut in ea recens caro lota esse videatur, in» terdum alba, nonnunquam nigra vel varia. Quapropter Graeci » morbum hunc *Χολέραν* nominarunt. Praeter ea vero, quae supra » comprehensa sunt, saepe etiam crura manusque contrahuntur, ur» get sitis, anima deficit, quibus concurrentibus non mirum est, si » subito quis moritur. Neque tamen ulli morbo minori momen» to succurritur." Cura, quam *Celsus* praescribit non minus huic morbo convenit quam ejus descriptio. Nam quum choleram biliosam ad-

(*) Operum omn. Gr. et Lat. T. I. p. 769. Lugd. Bat. 1665.

(**) De Medicina L. IV. c. XI.

admittat, rationi plane consentaneum est, quod dicit, » aquae tepidae « quamplurimum bibere oportet et vomere." — » At quum discussa » crudítas est, tum magis verendum est, ne anima deficiat. Ergo » tum confugiendum est ad vinum. — Si externae partes corporis » frigent ungendae sunt calido oleo, calidisque fomentis nutriendae."

Boerhavius, *Sydenhamus* aliique hunc morbum descripserunt, sed omnes eorum descriptiones pertinent ad illam affectionem, quae *Cholera Morbus* audit, qualis hodieque in Europa observatur; donec *Curtis* chirurgus nauticus, anno MDCCCVII ediderit historiam Cholerae Indicae, qua hunc morbum exhibet tanquam tunc temporis novum, neque in ullo nosologiae systemate aptum nomen reperiens, ab symptomate characteristico *Choleram Spasmodicam* appellari vult. Ejus vero descriptio ad hunc morbum non nisi in forma sporadica applicari potest.

Quod illam, de qua agimus *Choleram Epidemicam* attinet, quotidie auctorum numerus augetur, qui suas hoc de morbo observationes, vel ejusdem descriptionem in lucem ediderint. Nec mirum; in novo enim morbi genere quisque sibi licere putat suam edere theoriam, quum varia et mirabilis illius natura amplissimum scripturientibus aperiat campum.

Supra jam obiter memoravi duas me statuere hujus morbi formas plane diversas, nunc utriusque varietatis symptomata ac phaenomena, qualia ipse observavi, breviter exponam.

CHOLERA INDICA generis nomen esto; CHOLERAE STHENICAE et CHOLERAE ASTHENICAE appellatione utraque species distinguenda esse

mihi videtur. Hujus distinctionis ratio posita est in notabili ac specifica differentia, quae in primariis earum symptomatibus observatur, et denominatio a contraria universi systematis conditione desumta est. In posteriore enim, ut mox demonstrabitur, summa est virium collapsus ac terribilis ἀσθένεια, quum in priore specie excitatio et musculorum vis sit tanta, ut proposito nomine nullum aptius excogitari posse putaverim.

Illarum autem formarum frequentiorem et magis funestam prius describam.

III.

CHOLERA ASTHENICA.

Haec se prodere solet sensu quodam molesto, conjuncto cum anxietate circa epigastrium, qui in variis casibus vel brevius vel diutius adest. Aliquando vero hic morbus non praevia tali admonitione homines invadit. Vultus, qui primum molestiam tantum indicat, crescente morbo fit anxius ac moestus. Pulsus in prima periodo plerumque celerior est, semperque oppressus. Praeter ea eodem fere tempore aeger queritur de nausea et molesto sensu per intestinorum canalem; mox sequitur ventriculi et simul intestinorum abundans evacuatio, inanitatis et exhaustarum virium sensus, animi deliquium. Materia primum ejecta necessario constat iis rebus, quae ventriculo et alimentorum canali in ipso morbi impetu continentur.

Mus-

Musculi superiorum et inferiorum artuum haud aequabiliter contrahuntur. Spasmi plerumque sunt inordinati et quamquam in quibusdam casibus initio vehementiores, augescente morbo debiliores fiunt, et ante morbi finem ut plurimum omnino cessant. Post artuum contractiones spasmodicas musculi abdominales, denique thoracis ac diaphragma similibus spasmis afficiuntur. Sed dorsi, lumborum, vel faciei musculos ego quidem nunquam affectos esse animadverti.

Cum supervenientibus spasmis et intestinorum, evacuatione simul observantur surditas, aurium tinnitus, vertigo, extremorum prius, dein totius corporis frigus; scrobiculi cordis vehemens oppressio, respiratio difficilis, universi systematis collapsus; cutis magis magisque frigescit, quasi contrahitur, et in ulteriori morbi progressu sudore frigido obducitur. Facies jam apparet contracta, collapsa, cadaverosa, colore plumbeo, terroris et anxietatis plena, adeo ut totus aegri adspectus sit hominis lethali morbo correpti. Oculi amittunt vigorem, vitro similes fiunt, intra orbitas abditi, livido annulo cincti, cujus singularis habitus sufficiat ad hunc morbum detegendum. Pulsus paulo post primum impetum fit parvus, celer, oppressus, in corpore vix ac ne vix quidem percipiendus. Sanguis, si mitti potest, ater, spissus, oleosus, ita ut vere dicatur fluere instar picis liquidae vel theriacae. Arteriarum sanguis talis esse videtur, qualis venarum in sano corpore. Interea aeger queritur de ardore in epigastrio circa umbilicum, de siti inexplebili atque intoleranda, adeo ut, quamvis serio dissuadeatur, frigidam aquam poscere non de-

desinat. Labia sunt frigida ac livida; lingua pallida, muco quodam glutinoso obducta, frigida. Vomitus ac dejectiones alvinae nunc sunt frequentiores, et omnis materia ejecta fere prorsus eadem est, constatque liquore aquam oryzae referente, vel amylum aqua dilutum cum flocculis mucosis et substantia, ovi albuminis simili, innatantibus, nulla vero bile admixta (*). Progrediente morbo hae evacuationes minus minusque frequenter obtinent, ac plerumque paulo ante obitum cessant. Non tantum urina haud secerni videtur, sed etiam saliva et omnes glandularum secretiones prorsus supprimuntur.

Quo magis morbus ingravescit, eo magis observatur collapsus virium, corporis omnis superficies copioso sudore eoque frigido et viscoso magis et magis tegitur, ita ut speciem referat corporis aliquamdiu aquae immersi. Pedes manusque a principio sunt maceratae et rugosae; vox fit debilis, haud naturalis, sepulchralis, respiratio magis magisque suppressa, plerumque celer, sed interdum valde tarda. Imprimis notandum est, aërem, quem exspirat aeger, admodum frigidum esse. Homo, qui hoc morbo vexatur omnino inquietus conti-

(*) Quoniam nulla prorsus bilis erumpit, scriptores quidam in India objecerunt *Cholerae* nomen necessario hujus fluidi abundantiam involvere, quemadmodum *Celsus* loco supra allato clare docet; Χολὴ enim significat *bilem* et ῥέω *fluo*, adeo ut ad verbum esset *fluxus bilis*. *Trallianus* autem, praesentem respiciens morbum vocem nostram derivat ab alio nomine, quod *intestinum* significat, nimirum Χολὰς, et eodem verbo ῥέω; vi igitur vocis *Cholera* esset *intestinorum fluxus*, eoque magis convenit haec etymologia, quod materia non ex hepate, sed ex intestinis dejicitur.

tinuo sese jactat in lecto, extremam miseriam prodens et quamvis languore torpidus, inquietari haud patiens, loqui recusans, quamvis physice penitus prostratus, mentis tamen facultates ad ultimum vitae halitum retinet. Ubi ad moestae hujus scenae finem perventum est, anxius praecordiorum sensus increscere videtur, actiones vitales paulatim deprimuntur ac tandem prorsus evanescunt.

Haec morbi forma, si fatalis evadit raro ultra XXIV horas persistit, saepius vero intra VI, VIII vel XII horas, imo aliquando breviore spatio cursum suum absolvit. Diuturnitas autem hujus morbi pendet ex epidemiae praevalentis natura et violentia. In primo quidem ortu celerior ejus cursus fuisse dicitur, quam quum mihi illum observare contigit.

Haec solita sunt Cholerae Asthenicae symptomata, ordine, quo sibi succedere solent. Ex variis autem descriptionibus, quae ex India ad nos pervenerunt, concludere oportet, pro diversis locis non solum diversos esse violentiae gradus, sed etiam multas varietates in symptomatum successione, nec minus in celeritate, qua cursum suum absolvit. In aliis casibus nullus est vomitus, in aliis nulla dejectio alvi, in aliis nullus spasmus. Hae quidem longe periculosissimae sunt formae. Aeger quasi sine lucta succumbit, pariter atque ille, qui morsu lethali serpentis, quem *Cobra di Capello* vocant, subito perit.

Talis est progressus Cholerae Indicae forma asthenica, morbi, quo non alius terribilior reperitur, nec minus medicorum curationi obediens. Qui aliquando ejus saevitiam spectavere medici, eam nunquam obliviscentur, neque sine horrore ac tristitia in memoriam revocabunt.

tim forma Sthenica, dummodo in tempore convenienti curatione ei succurratur, saepe in primo ortu opprimi posse, vel saltem prohiberi, ne ad eum violentiae gradum se extollat, quo sibi relictus certo perventurus esset.

V.

DE CAUSIS ET ORIGINE MORBI.

» Felix qui potuit rerum cognoscere causas."

Variae prolatae fuerunt conjecturae de causis Cholerae Indicae Epidemicae, sed hae omnes hactenus nobis parum satisfecerunt. Quum vero »Causae proximae investigatio", ut *Celsus* ait, »ad cognitionem morbi ducit amplissimam" innumera collegimus rerum testimonia.

Choleram Epidemicam morbum esse malignum, nemo facile dubitaverit. Ex historia autem progressuum, quos fecit, primo obtutu videri possit, generatam et dispersam esse peculiari quodam contagio. Quae opinio quum medicos gravissimos patronos nacta sit, operae pretium mihi visum est, quaestionem, de qua tantopere disputatum fuit, paulo accuratius persequi.

Ut opinionem suam, contagio propagari morbum confirmarent, his

his usi sunt argumentis: Tantum abesse, morbum ventorum cursum aut solis potentiam aut cujuscunque meteori efficaciam sequi, ut potius contra omnigenum atmosphaerae impulsum continua stationum serie procedat: eodem vehementiae gradu quolibet anni tempore eum grassari, in temperatura 40° vel 50° ad 90° vel 100° thermometri *Fahrenheitiani;* tam pluvia per complures menses cadente, quám coelo tam aridо atque ardente, ut vegetationis ne vestigium quidem in terrae superficie cerneretur. Accedit quod saepe per statos illos Indici maris ventos, quos *Monsoons*, vocant, viam sibi patefecerit; quod varias regiones, per quas in cursu suo penetraret, intactas reliquerit, quamvis insalubritatis fama cognitas; quod denique in quavis lunae vicissitudine, in omni atmosphaericae electricitatis conditione, tam mari quam terra et apparuerit et evanuerit. Hanc argumentationem suam confirmare conantur hoc in primis exemplo, quod in insula *Mauritii* Cholera non fuerit orta, ante quam ex *Ceylano*, ubi iste morbus regnabat, nave quadam advecta esset. Nonnulli scilicet nautarum, qui in illa nave vehebantur, in itinere Cholera correpti erant, quamvis omnes, quum navem solverent, secunda valetudine essent usi (*). Hinc demonstrare volunt, in nullam urbem neque

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(*) Si concedamus verum esse, dictam navem *Ceylanum* reliquisse omnibus nautis bene valentibus, et morbum non exstitisse, nisi illis aliquamdiu in mari navigantibus, nequaquam inde sequitur per contagium propagari Choleram. Inter omnes constat homines, qui versati erant in regionibus febri obnoxiis, domum aliquando rediisse, integra, ut videbatur, valetudine, et paucis mensibus post, in

regionem epidemiam illam irrupisse, ubi omnis communio fuerat interclusa cum iis locis, in quibus ea regnabat.

Ab altera parte, si ejus historia accuratius examinatur, apparebit, multiplicia esse facta, quae nullo modo ad cognitas contagii leges referri possint: v. c. cum his legibus non congruit casus singularis ac vulgo notus, qui in nosocomio quodam aegris pleno accidit. Homo nimirum nescio cujus morbi causa ibi receptus, subito Cholera afficiebatur ac mox moriebatur. Idem tamen morbus in eodem nosocomio non iterum exoriebatur, etsi in vicinia undique grassans. Non minus vulgo notum est, illos, qui Cholera affectos curant, vel qui in eadem domo vivunt, vel in eodem lecto cubant non magis isti morbo obnoxios esse, quam illos, qui multis milliaribus ab iis distant. Quod praeterea Cholerae ortum in aliquo loco attinet, eodem temporis puncto multi ea corripiuntur, qui et diverso vitae genere et domiciliorum distantia, eam nullo modo secum possint communicare (*).

Haec

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in febrim incidisse, nihilominus tamen in illis regionibus semina morbi nata erant. Pari modo nautae *omnes* dictae navis causis excitantibus expositi erant, quum ad pestifera illa *Ceylani* littora in anchoris starent, neque necesse est *unum* eorum forte morbum sibi contraxisse atque ita cum ceteris communicasse.

(*) Limites hujus dissertationis excederem, si multifariis exemplis probare conarer Choleram Indicam non esse contagiosam. Lectores malo ablegare ad Commentarios medicos Bombajae editos, (*Bombay medical Reports*,) qui de hoc argumento accurate ac docte scripta continent. Reperiuntur ibi complura exempla militum legionis cujusdam Cholera misere afflictae. Quae quamvis cum militibus alterius legionis libere versaretur, contagio tamen neminem eorem inficiebat.

Ceterum hunc locum qui ad obscuras contagionis leges pertinet non ulterius persequar. Sufficiat, me in praxi mea nihil vidisse, unde colligendum sit contactu hunc morbum propagari. Est autem quod doleamus, opinionem istam fuisse traditam ac facile arreptam, adeo ut metus contagii non solum causa facta sit praedisponens morbi, sed etiam non paucos absterruerit a curandis ac juvandis hominibus, gravissima illa calamitate afflictis.

Complurium vero est opinio choleram in India oriri ex malignis, exhalationibus decompositione vegetabilium, quibus illa terra abundat, immensa copia nascentibus. Anno MDCCCXV (*) et duobus proxime sequentibus, coelum fuisse solito ardentius dicitur et parum pluviae cecidisse. Observatum autem est, vehementissimas epidemias in omnibus terris exortas esse post calidissima atque aridissima tempora; hoc tamen non eo valet, ut inde explicari possit epidemia, quae effectus habuit plane singulares. Ejusmodi causa occasionalis jam ante annum MDCCCXVII obtinuisse necesse est. Hinc patet, quam parum nobis notum sit cum de actione malignae atmosphaerae, tum de epidemicorum morborum natura et oeconomia.

Non dispar difficultas est in explicando Febris Intermittentis repetito im-

(*) »Multi morbi tam Epidemici, quam alii suo ac proprio tempore erumpunt; »falso id imputatur aëris per id tempus constitutioni, quo erumpunt vel grassan»tur; quum quidem ex praecedente et sequente causa ac tempestatum anni »serie oriantur. Quamobrem *Hippocrates* in prognosticis suis bonas observatio»nes habet morborum, qui indolem praecedentium anni tempestatum sequuntur." BACON. Oper. vol. I. p. 375, Ed. Angl.

ubi tamen Cholera saepius impetu erupit vehementissimo. In mortuis autem Indigenis, militibus, (*Sepoys* dictis,) major, quam in Europaeis congestio sanguinis observata est, priorumque incredibilem multitudinem Cholerae epidemia abreptam esse vidimus. Hujus rei causa verisimillima in simplicissimis eorum alimentis posita esse videtur, sic ut a priori in contrariam consequentiam induceremur, considerantes illos longe melius, quam Europaeos ardentis solis actioni colore cutis resistere posse. Verum a proposito nostro alienum est, de solis tropici actione in Europaeorum constitutionem hic accuratius disceptare, quod a Doct. *Johnson* aliisque eximie factum est. Hoc tantum notamus solis radios inter causas, corporis humani constitutionem debilitantes, atque adeo ad Choleram praedisponentes, primum locum tenere.

Res notissima est, si, nave in Indiam appulsa, Cholera forte corripuerit nautas, efficacissimum morbi cohibendi remedium esse, rursus anchoram solvere. Plura docuerunt exempla, vehementissimum morbi furorem, qui omnibus vectoribus necem minabatur, hoc modo adhibito coërcitum esse. Similiter constat saluti militum optime consultum esse castris ex loco, ubi Cholera grassabatur, alio translatis.

Supra memoravi anno MDCCCXXVII Choleram in australi *Bengalae* parte terribilem edidisse stragem; quum vero impetus, quem Anglicis navibus in portu quiescentibus, Junio, Julio et Augusto mensibus, intulit, cum singularibus conjunctus esset accidentibus, quae ipse observavi, non abs re mihi esse videtur, quantum po-

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tero, accurate describere phaenomena ad hoc gravissimum, nec minus obscurum argumentum pertinentia. Non vero alienum sit praemittere loci, ubi morbus grassatus est, succinctam descriptionem.

Portus *Saugorensis* in ostio fluminis *Hoogly*, uno ex oribus *Gangis*, situs est, Latitud. Septentr. 21°, 36′ ac Longitud. Oriental. 38°, 11′ atque fere centum et decem milliaribus infra urbem *Calcuttam*. Amnis hoc loco octo ad novem miliaria largus; orientem ac septentrionem versus terminatur uliginosa insula *Saugor*, immensisque illis paludibus, (quae *Sunderbunds* vocantur), ac trecentis fere milliaribus, ad majora *Gangis* et *Burrhampootae* ostia usque. se extendunt. Universa haec regio vastis ac fere impenetrabilibus sylvis, (quae *Jungles* appellantur,) consita est, quarum major pars, pluviarum praesertim tempore, aqua est superfusa; unde fit, ut arbores quam citissime crescant, ac totius regni vegetabilis luxuria merito admirabilis sit.

Navis, qua vectus sum, antequam ad *Bengal* perveniret ad *Madras* appellebat; vectores, quod exspectari poterat, fructuum tropicorum, qui illic abunde adsunt parvique veneunt, magnam copiam avidissime comedebant. Brevi, quatuor tantum dierum itinere per sinum *Bengalensem*, plures, illa imprudentia atque intemperantia, Diarrhaeam sibi contraxisse apparebat.

Navis octavo die Junii adventabat ad *Saugorensem* portum quum status ille Indici maris ventus, (qui *Monsoon* vocatur) inter meridiem et occidentem spiraret. Decimo septimo ejusdem mensis die vehemens ex eadem coeli plaga exoriebatur flatus, ac largissimi cade-

bant imbres. Proximo autem die, ventus subito se vertebat in orientem, mox boream inter et ortum, violenter mugiens, multum etiam pluviae decidebat. Noctu nec flare nec pluere desinebat, ac die decimo nono horis matutinis, ventus magis ad septentrionem conversus incitatiore impetu spirabat; meridiano autem tempore mitescebat, ad pristinam plagam, meridiem inter et occasum, conversus. Nocte illa fatali, virus exitiale conceptum est aëre, qui trecentorum milliarium spatio ex paludibus supra memoratis irruens, noxio vapore impraegnatus, pulmones inspirantium ita afficiebat, ut suffocationem breviculam cum levi tussi excitaret; quod complures Praefecti mecum experti sunt. Hujus miasmatis effectus adeo formidabam, ut navis fenestrae, vento objectae, statim clauderentur, et per totam noctem clausae manerent, ne homines per somnum nocivo aëre infestarentur.

Eodem die singularis casus evenit; homo quidam, qui paucis ante diebus in insula *Saugor* fuerat, humiditate et frigore affectus, Asthenica Cholerae specie altero mane occubuit: Brevi hoc temporis spatio morbus adeo processerat, ut nocte diei XXI, sive postero mane intra tres horas tres homines amitteremus. Quanta tristitia hic imminentis mortis adspectus cunctos adfecerit, facile quisque intelliget,

Utraque forma morbus grassabatur; horis singulis recentes casus incidebant, et vi causarum praedisponentium numerus mortuorum quotidie augebatur. Illi, qui diarrhaea laborabant, ipsi intelligebant se Cholerae magis obnoxios esse. Aegrotantium catalogus jam tertiam, imo dimidiam partem nautarum continebat; hinc validis

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duplo munere fungendum erat, idque tempore calidissimo, quum thermometrum *Fahrenheitianum*, in umbra suspensum, 90° vel 94° indicaret. Labor igitur continuus nautarum, qui insuper sociorum defunctorum corpora scaphis in littus transferendi triste officium obibant, abjectio animi extrema, quum quid sequenti hora sibi eventurum esset, nemo sciret, haec omnia morbi impetum faciliorem reddebant. Maxime vero memorabile est, in omnibus casibus, qui nobis obveniebant, ne unum quidem ex Praefectis vel horum ministris, morbo correptum esse; quos et lautiora alimenta, et vini usus modicus, et vestimenta corpus melius tegentia, a morbi impetu tutos servavisse, evidens est. Ex hac re singulari, per se notatu digna, concludere licet, Choleram illam secutam esse ventum, noxiis effluviis valde impragnatum, postquam paludum vastum tractum perflaverat, eandemque gravissima clade afflixisse nautas, dictis causis ad eam praedispositos. Observatione quoque dignum est, ex septem aliis navibus, eundem portum tenentibus, vix quingentos passus distantibus, pari hominum numero, parique commeatu instructis, atque eodem tempore ex Anglia profectis, nostram solam in horribilem istum morbum tantopere implicitam fuisse. Pauci tantum casus quibusdam ceterarum navium contigerunt, aliae, credo, prorsus immunes fuerunt. Notandum praeterea unam earum nobiscum ad *Madras* pervenisse, cujus nautae in *Bengal* non praeter morem aegrotaverant.

Denique non praetermittendum censeo, ex numero centum et quadraginta hominum, (quorum XXXVI erant Praefecticum eorum ministris,

ceteri CIV nautae) XXXVI Cholera laboravisse, et IX quidem Sthenica, qui omnes convaluerunt, XXVII Asthenica, quorum XV servati sunt, sed XII mortui.

VI.

DE DIAGNOSI.

Quum hic sit morbus sui generis, vix necessarium esse videtur prolixius de hoc capite disserere; ordinis tamen gratia quaedam signa diagnostica breviter notabo.

In Cholera Asthenica nullum signum frequentius est, quam ater, spissus ac fibratus sanguinis habitus; qui, si consideratur una cum debili exhausto actionum vitalium statu, cum praeternaturali corporis externi specie, cujus superficies sudore roris instar obtegitur; adde rugas ac frigus extremorum, vultus anxietatem, lividum, oculos cingentem, annulum; quod ea, quae vomitu et dejectione alvina evacuantur, nulla bile sunt mixta; quod naturales secretiones interruptae sunt; quod cordis et arteriarum actiones jam in principio morbi deprimuntur; denique, quod in multis casibus, vomitus, alvinae dejectiones ac spasmi prorsus desunt; haec omnia sufficiunt ad hunc Cholerae speciem accurate distinguendam a morbo, quocum confundi possit, Cholera scilicet illa quae ante annum MDCCCXVII vulgo observari solebat.

Quum phaenomena non adeo sensus feriant, nec formidinem incutiant, quodnam sit discrimen Cholerae Sthenicae et Sporadicae,

non

non tam perspicue definiri potest. Verum insignis spasmorum vehementia, eorum in morbi initio ortus, ac rapida per extremitatum superiorum ac thoracis musculos extensio, saepe nullo praecedente malo, peculiaris calor epigastrii, intoleranda sitis, nulla bilis materiae evacuatae admixta, ac praesertim pulsus plenus, fortis et celer, haec omnia sunt phaenomena, qualia in nullo alio morborum genere simul conjuncta deprehendimus.

VII.

DE PROGNOSI.

In Asthenica morbi hujus forma, si medicus non viderit aegrum antequam omnia symptomata se plane manifestaverunt, quando pulsus in carpo plerumque sentiri nequit, parum auxilii ars humana afferre potest. Quamvis aliquando accidat, ut ejusmodi aeger convalescat, illud vel casui fortuito, vel firmae corporis constitutioni magis tribuendum est, quam remediis adhibitis, aut medici prudentiae et judicio. At si deprehendimus virium vitalium incrementum, pulsum pleniorem, caloris in extremitates reditum, et auctum in corporis superficie ardorem, minus vehementem sitim, diminutum ardoris in epigastrio atque circa umbilicum sensum, urinam mittendi conamen, praesertim si revera excernitur, respirationem minus laesam, aërem, quem aeger exspirat, minus frigidum, ad somnum proclivitatem, majorem oculorum vigorem, la-

labia, linguam atque os magis rubra ac sanitatis signa recuperantia, si aeger tranquillior fit et minus se in lecto jactat, praesertim si in dejectionibus aliquantum bilis apparet, tum est, quod speremus prosperum morbi exitum.

Sed ab altera parte si symptomata, non obstantibus remediis adhibitis, augentur, si respiratio vel admodum lenta et oppressa, vel praeter naturam celer ac laboriosa est, ita ut aeger anhelatione urgeatur, quum cordis actio adeo imminuitur, ut nullus pulsus in extremitatibus percipiatur, quum facies demissa est, atque collapsa, si lingua et os frigescere incipiunt, cum cornea subsidit atque obfuscatur, cum jactitatio perseverat, sed spasmi, vomitus et alvinae dejectiones simul cessant, tum de aegri salute desperandum est, quando quidem exhaustam vim vitalem restituere non valeat medicina.

In Sthenica hujus morbi forma, plerumque bonus exitus praedici potest, maxime si debito tempore apta remedia a prudente medico adhibita fuerunt, antequam vitae vires inordinata musculorum actione exhaustae sunt. Gravissimis symptomatibus, necnon vehementibus remediis constitutionem aegri admodum concuti facile intelligitur, indeque eum tarde vires ac pristinam sanitatem recuperare. Quamobrem oportet omnem adhibere curam, ne in eundem morbum recidat, atque adeo cavendum, ne nocturno tempore prope paludes se aëri exponat, aut intemperantia qualicunque peccet. Novo enim morbi impetu sanationem difficiliorem, ac aegri conditionem magis periculosam reddi, nemo rei peritus dubitabit.

VIII.

CADAVERUM INSPECTIO.

Cadaverum dissectio adhuc parum lucis huic morbo affudit, sive quod causam proximam attinet, sive quoad symptomata, quae illum comitantur: imo ex organorum conditione saepe mortis causa explicari non potest. Hominum, qui Cholera occubuerunt, cadavera ea qua par est, diligentia examinata sunt; verum cujusque examinis fructus eo praesertim rediit, ut, quod a priori exspectari poterat, confirmaretur; nempe adesse insignes congestiones venosas in omnibus corporis partibus et praesertim in intestinis tenuibus. Breviter tamen diversorum organorum statum exponam; atque ab iis incipiam, quae maxime conspicuas mutationes subierant, *Intestinis* scilicet *Tenuibus.* Abdomine aperto saepius foetor peculiaris observabatur, praesertim in iis, qui subito extincti erant. Intestinorum tenuium venae nigro sanguine fere semper turgebant; externa eorum superficies spisso ac viscoso humore erat tecta; eorum color, a pallide cinnabarino per omnia discrimina ad obscure purpureum usque varius deprehendebatur, quum prior color maxime conspicuus esset in tunica externa Duodeni et Jejuni, posterior in ea Ilei, ubi in Caecum desinit. Intestinis juxta longitudinem dissectis, tunicae eorum videbantur incrassatae, maxime ubi non distenta erant flatu, aut quodammodo contracta. Erant saepe emollita, ac solito facilius rumpebantur. Membrana interna plerumque inveniebatur tecta lym-

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pha spissa, vescide lutea, interdum flavescente, quod imprimis observabatur in iis, qui subito brevique Cholerae impetu obierant. Hac lympha plastica remota, ipsa tunica mucosa in superiore intestinorum tenuium parte plerumque pallida erat, sed in inferiore parte coloris obscuri, ad purpureum vergentis, ubi etiam tunica externa caerulea vel purpurascens observabatur. Muculae caeruleae, obscure rubrae vel purpureae, in variis horum intestinorum partibus interdum observabantur, quae locis, in quibus aegri in primo morbi impetu se maximum dolorem sentire questi erant, exacte conveniebant. *Intestina Crassa*, plerumque erant pallida ac flatu distenta, aliquando contracta in nonnullis locis, colorem purpureum, congestione in systemate venoso ortum, exhibentes. Nunquam in iis reperiebantur faeces, sed, fluidum, in illis obvium, ut plurimum erat simile fluido, quod tenuibus intestinis continebatur. *Ventriculus* fluidi aquosi, turbidi, interdum grumosi, majorem minoremve copiam continebat; externa ejus tunica congestionem venosam, solito majorem, exhibebat. Interna tunica admodum rugosa, inspissata, et, ubi tangebatur, emollita erat. Ejus tunicae pariter ac intestinorum tenuium digitis facile rumpebantur. In illis casibus, in quibus aliqua vis vitalis supererat, interna ventriculi superficies, prope pylorum, colorem laetiorem, rubescentem monstrabat atque ibi spissior et magis contracta apparebat.

Hepar coloris erat solito obscurioris et sanguine crasso, nigro, nonnunquam purpureo vel intense caeruleo repletum, alio tempore erat maculosum, magnitudine auctum, molle, pulposum, ac ruptu fa-

facile; magnae ejus venae non secus ac venae totius cavitatis abdominalis, sanguine nigro ac grumoso, de quo saepius mentio facta est, turgebant. *Vesica Fellis* semper inveniebatur distenta, felle spissa viscida, coloris plerumque obscure viridis vel nigri, et quamquam ductus magni ac permeabiles essent, bilis non propellebatur in duodenum, nec sine majore pressione eo perduci poterat. *Splen* in plerisque cadaveribus erat magnitudine auctus, et ut caetera viscera atro sanguine turgens, texturae solito mollioris, levi attactu plerumque rumpebatur. *Renes* haud affecti, sed prorsus sani videbantur; nullum vitium organicum aderat, ex quo posset explicari, cur per omnem morbi decursum eorum functiones plane essent interruptae. *Vesica Urinaria* erat vacua et contracta, nec qualecunque morbi indicium exhibebat. *Cor* sanguine nigro, crasso ac viscido turgebat, ejus substantia erat mollis ac laceratu facilior, quam in hominibus sanis esse solet.

Pulmonum substantia erat incrassata, atque hepatis substantiae simillima, dum ipsorum venae sanguine etiam quam maxime turgebant. *Cerebrum* inveniebatur sanum, sed congestione venosa solito magis turgens, dum ipsius ventriculis aliquando praeternaturalis collectio humoris gelatinosi vel serosi continebatur. Haec omnia, plerumque in Europaeis et in Indigenis observabantur; quum vero in his morbi cursus celerius terminetur, congestio etiam in plurimis casibus erat gravior, paritr atque in iis Europaeis, in quibus terminus fatalis morbi invasionem citissime insequebatur.

IX.

DE RATIONE MEDENDI.

Indicationes in utraque morbi forma hae sunt, ut congestio tollatur, secretiones naturales promoveantur, et circulationi sanguinis aequilibrium reddatur. In altera specie juvat scire, fore ut remediis convenientibus prompte adhibitis plerumque his consiliis satisfiat; in altera vero saepe dolemus, morbum quidquid nitamur, fataliter decurrere, ita ut nullis auxiliis, de quibus mox agemus, cohiberi possit. Utriusque speciei Cholerae ratione habita in duas sectiones hoc caput dividemus.

A. *De Cholerae Asthenicae Curatione.*

Successus curationis, ut hoc praemoneam, pendet ex tempore, quod ab ortu morbi elapsum est, adeo ut hic quoque valeat tritum illud *Nasonis* praeceptum:

»Principiis obsta, sero medicina paratur,"
»Si mala per longas invaluere moras."

Hinc magni momenti est medicum cognita habere prima symptomata, quae in ipso morbi impetu adfuerunt; qualia sunt molestus in epigastrio sensus, anxietas in vultu aegri conspicua, facies collapsa et contracta, quasi sanguis subito desierit manare versus superficiem, atque, ut revera accidit, in interioribus corporis partibus collectus remanserit. In hoc stadio *Sanguinis Missio* efficacissimum est re-

medium, adeo ut si sanguinem fluere videmus, nos servaturos esse aegrum quodammodo ominari licet. Adspectu quidem primo mirum videri possit, sanguinis detractionem praescribi in morbo, cujus manifesta symptomata sunt, debilis pulsus, frigus per totam corporis superficiem, ac virium vitalium generalis depressio. Verum quum haec symptomata oriantur ex sanguinis irregulari circulatione, atque in viscerибus congestione, non dubitari potest, quin sanguine detracto haec causa subito tollatur; ita enim cordis actio incitatur atque circulatio sanguinis non parum promovetur. Quandoquidem vero, ut modo dixi, si sanguis emitti potest, illud plus auxilii, quam ullum aliud remedium affert; dolendum est, in nimium multis casibus sanguinem e sectis venis imo vel ex arteriotomia non prodire. Non tamen hoc in casu desperandum est, sed omni ope nitendum, ut sanguinis, cujus naturam crassam ac viscidam descripsimus, circulatio restituatur. Non igitur in sola vasorum apertura acquiescendum, sed frictiones quoque adhibendae sunt. Quanto enim plus sanguinis detrahitur, eo celerius curret, pulsus augebitur, atque obscurus sanguinis color in laete rubrum mutabitur, atque adeo faustus exitus praedici quodammodo poterit.

Venae sectioni succedunt *Stimulantia*, inter quae Spiritus Vini (*), et Opium primum locum obtinent; haec summa dosi propinanda, incipiendo ab octoginta guttis Laudani et cyatho spiritus vini calida aqua mixti, nec vero nimis diluti. Aether quoque, ammonia, camphora

(*) Anglicè *Brandy*.

similiaque a multis adhibentur, sed ventriculo non admodum conveniunt; ego quidem minus probo consilium, ventriculum variis stimulis onerandi. Interdum, si spiritum vini non conducere deprehendimus, validioribus stimulis utendum est, sed in plerisque casibus convenit illud remedium, palato gratum, et aegrotantium custodibus tuto committendum. Si itaque inde nihil opis experimur, multo minus ex aethere aut ammonia expectari poterit. Non diu post primum spiritus vini et aquae cyathum, integra dosis, i.e. gr. xx. Submuriatis Hydrargyri administranda est, postea vero parvis intervallis, minor dosis, e. c. v. granorum cum Opii granis duobus.

Balneum Calidum maxime commendatur, una cum venae sectione eodem tempore instituenda, si forte alia remedia successu caruerint. Calor quidem corporis superficiei applicatus sine dubio magnae esse utilitatis; sed ab altera parte saepius nocet corporis agitatio, dum aeger e lecto in balneum transfertur, evaporatio et caloris animalis amissio, dum detergetur, vel, si hoc non fiat, etsi stragulis humidis involvitur, brevi tota corporis superficies frigescit, atque sic effectus producuntur consilio curationis plane contrarii. His rationibus inductus, balnei usum prorsus rejecto, aliam et minus incommodam, et magis convenientem corpus aegrotantis calefaciendi viam ingressus sum; ampullas nempe, aqua calida plenas, ad pedes, epigastrium, aliasque corporis partes apponendas curavi. Pro ampullis alia vasa, etiam utres et vesicae adhiberi poterunt. Sed etiam quam maxime cavendum ne stragulis semotis caloricum dissipetur. Hoc tamen consilium nimis frequenter frustrabatur; spasmi enim supervenientes

saepe postulant, ut frictionibus continuis levamen aliquod miseris illis hominibus afferratur. Quum modo de hujus, modo de illius femoris molestia, nunc de brachii, nunc rursus de femoris dolore querantur, atque semper inquieti in lecto se jactitent, non diu stragulis coopertos illos manere sponte intelligitur (*).

Quod *Linimenta* attinet frictionibus inservientia, illa quae natura sunt oleosa ac stimulantia, spirituosis praeponenda sunt, quoniam vaporationem non adeo augent. Linimenta usitatiora sunt Liquor Ammoniae fortior cum Oleo Olivarum, (in Pharmacopaeia Belgica *Sapo Ammoniae* dictus), Oleum Terebinthinae cum Oleo Olivarum, similiaque. Nullum vero tam efficax est quam illud quod India profert, Oleum Cajeputi, (*Hindustani*, *Kayapootee*), remedium valde diffusile, stimulans, odoris grati. Interne illud adhibui ad XL guttas pro dosi in potionibus, ut videbatur, non sine fructu, sed quum mihi occasio defuerit illud saepius administrandi, non confidenter ejus usum commendare ausim.

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(*) Post ea vero ex celeberrimi Doctoris *Armstrong* lectionibus Aëris Calidi Balneum cognovi, tam simplex quam ingeniosum inventum, quod, ut mihi videtur, utilitatis summae esse poterit in Cholera, quando scilicet aeger non perturbatur spasmis. Auctor illud valde commendat in Febre Congestiva, morbo phoenomena exhibente nonnulla, qualia in Cholera Indica quoque cernuntur. Machina adhibenda simplisissima est, formae fornicatae, viminea, sex fere pedibus longa, una parte aperta, altera ligno obstructa, cujus centrum foramine pertusum est. Haec machina aegro in lecto decumbenti imposita, ac stragula una et altera, circa collum aegrotantis constringenda, tegatur. Quo facto, tubus stanneus, cujus orificio lucernula affixa est alcohole repleta, inseratur dicto foramini inferioris machinae partis. Alcohole accenso totus apparatus absolutus est, dum nunc combustione alcoholis, aëris temperatura qui aegroti corpus circumdat, sufficienter adaugetur.

Vesicatoria a quibusdam admodum commendata sunt; mihi tamen dubius est eorum usus in hoc morbo. Cantharides enim nimis lente vim suam exserunt in hoc morbo, qui saepe incredibili celeritate periodos suas percurrit. Sed si laminis ferreis aqua bulliente calefactis et corpori admotis, statim cuticula in vesiculas attollitur, illud conducere potest, praesertim cum dolor in epigastrica vel umbilicali regione adeo urget, ut neque externa neque interna remedia ullum levamen attulerint.

Haec sunt remedia maxime probata in hac morbi specie; eorum vero applicatio ac repetitio instituendae sunt pro re nata et secundum curae indicationes. Constitit mihi experientia spiritus vini dosin vakde esse indeterminatam. Aliquando duas libras, sine ullo detrimento vel incommodo, aegri sumserant, imo non paucorum sanitatem largo hujus remedii usu restitutam esse mihi persuasum est.

Periodi hujus morbi saepe tanta celeritate absolvuntur, ut non nisi prompta applicatio remediorum efficasissimorum morbi progressum cohibere possit. Hinc constans medici praesentia, et continuata administratio remediorum memoratorum requiruntur. Nemo sane excusari poterit, si aegrum deserat, antequam affirmare possit, quo se conversurus sit morbus; quod saepe intra duas tresve horas fieri potest. Saepissime tamen dolebamus, conamina nostra aegri restituendi sperato successu caruisse, praesertim in iis casibus, in quibus non observabantur vomitus, nec plures quam una vel duae alvi exonerationes liquidae, nullus spasmus qui percipi possit, nec dolor ullus; quando jam ab invasione morbi frigus universale

quasi mortui a suppressa sanguinis circulatione in aegro percipitur, atque ita vires ejus diminuuntur, ut plerumque sine certamine, ac saepe intra duarum, trium, vel quatuor horarum spatium exspiret.

B. *De Cholerae Sthenicae Curatione.*

Ut Asthenica hujus morbi forma curam reddit difficilem ac medici animum deprimit, ita Sthenica, de qua jam agendum erit, facile curatur atque prospero successu medicum exhilarat. Jucundissimum est profecto videre quam efficax saepe sit auxilium, aegro qui dolore vehementissimo excruciabatur, chirurgica operatione allatum, aut administratione Hydrargyri in sistenda inflammatione, quae Iritidem, aliasque non minus graves morbos, comitatur. Sed multo magis conspicuus est effectus copiosae sanguinis detractionis in Sthenica Cholerae specie. Illud enim remedium, bene adhibitum, indubitatum levamen affert. — Quum autem indicatio sit manifesta, et curandi methodus una, eaque faustum exitum promittens, ea, quae hoc capite observanda sint, paucis verbis comprehendere possumus. Incipimus, quemadmodum in altera specie morbi, largam Calomelanos dosin administrando, tum sequitur venae sectio, quam plerumque utriusque brachii venis incidendis perfeci. Quantitas vero sanguinis detracti non adeo respicienda est, quam quantum levaminis phlebotomia afferatur. Quo maturius autem fiat haec operatio, eo citius relevabitur aeger, eoque minus frangentur vires, quae ad convalescendum tam necessariae sunt, quae amissae non celeriter recu-

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exhortantur, ut omnes intendamus nervos ad mortem imminentem, si fieri possit, propulsandam. Eadem divisio praeterea contrarias de isto morbo relationes conciliat; illae enim adeo inter se discrepant, ut aliae duos, aliae quinquaginta homines ex centenis Cholera laborantibus interiisse tradant. Doctor *Burrell* (*) se LXXXVIII ex XC servavisse contendens, nullum dubium relinquit, cujus formae fuerit Cholera quam faustissimo successu curavit; »Vomitus," inquit, »erant continui, et spasmi tam vehementes, ut sex homines re»quirerentur, qui aegrum in strato tenerent." Imo experientissimus *Craw* apud *Seroor* asseverat morbum, sua opinione non magis, quam in uno ex centum casibus fatalem esse (**).

Operae pretium sit inquirere, sitne Sthenica forma Cholerae Indicae hodie frequentior, quam olim. Certum est, illam multo magis grassari inter Europaeos quam inter Indigenas, quod merito expectari potest ex diversitate eorum constitutionis. — Haud necesse erit, me longiorem esse in enarranda strage, quam hic morbus inde a primo ortu in India edidit; quippe quae per totam Europam non medi-

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(*) *Bombay Medical Reports*, pag. 68.

(**) Postquam haec scripsi, non sine aliqua voluptate sequentia legi: » Dom. » *Mc. Cabe*, Chirurgus in oppido *Poonamallee*, me certiorem facit, se reperisse » casus, qui et vulgari observatione videri possint desperati, tales scilicet, quos » spasmi vehementissimi et vomitus concomitabantur, sed revera essent mi» tissimae indolis; observatio sane magni momenti, quam experientia mea pla» ne confirmavit".

Orton's Essay on the Epidemic Cholera.

cis solum, sed vulgo innotuit. Aliqua tamen notio hujus calamitatis informari potest ex Commentariis Medicis Bombayensibus (*). Numerus incolarum illius provinciae censetur CC, vel CCXX mille capitum; ex his constat XV mille DCCCCXLV homines, id est, septimam et dimidiam partem universorum incolarum, Cholera correptos fuisse, quorum MCCXCIV, nulla medicorum ope sublevati, ad unum omnes interierunt.

Diram Cholerae cladem, quam expertus est exercitus Britannicus, quum illustrissimus Marchio *Hastings* Indicas provincias gubernaret, memoria tenent omnes, qui testes oculati supersunt. Tunc una die ultra D homines horribili illo morbo interemptos esse ferunt. Subita caedes, qua afficiebantur homines, saepe quoque memorata est; interdum enim tribus vel quatuor horis post primum impetum mors insequebatur. Notissima sunt exempla in *Hoogly* aliisque locis, Indos sub aperto coelo ambulantes, subito fatali morbo percussos, humi cecidisse, vomuisse paululum et de vertigine, surditate ac caecitate conquestos, brevissimo temporis intervallo animam efflavisse. In *Bellary* sartor quidam morbo correptus, qui Cholera putabatur, in eodem corporis habitu, quo operi intentus sedebat, expirasse perhibetur (**).

Forte non abs re erit ex historia Cholerae, quae anno MDCLXIX in Anglia epidemica fuit, atque ab accurato fideque digno observatore Sy-

(*) *Bombay Medical Reports*, p. 82.

(**) Vid. *Orton's Essay on the Epidemic Cholera*, p. 41.

Sydenhamo descripta est, comparationem aliquam instituerit. De fatali ejus rapiditate vir celeberrimus ita loquitur, ut proxime accedere videatur ad Choleram, quae hodieque in India grassatur. Expositis symptomatibus notabilioribus, concisam hanc observationem subjungit: »Cum multis aliis symptomatis, quae astantes magnopere per»terrefaciant, atque etiam angusto viginti quatuor horarum spatio »aegrum interimunt." Septennio post, anno MDCLXXVI agit de epidemico morbo, qui indolem assumserat magis affinem Sthenicae formae Cholerae Indicae; quamvis enim convulsiones essent vehementiores, quam quales unquam ante viderat, non videtur morbus magis exitiosus fuisse, imo tantum aberat, ut intra XXIV horas aegros interimeret, ut potius largae Laudani liquidi Sydenhami dosi cederet. »Exe»unte aestate," ait, »Cholera morbus epidemice jam saeviebat, et »insueto tempestatis calore evectus, atrociora convulsionum sym»ptomata eaque diuturniora secum trahebat, quam mihi prius unquam »videre contigerat; neque enim solum abdomen, uti alias in hoc »malo, sed universi jam corporis musculi, brachiorum crurumque »prae reliquis, spasmis tentabantur dirissimis."

Res notatu digna esse videtur Sydenhami morbum epidemicum accidisse annis MDCLXIX et MDCLXXVI, et Dellonum edidisse suam de Epidemia Indica dissertationem anno MDCLXXX, hunc saltem annum fert dissertatio ejus. Profecto parum novimus de epidemicorum morborum natura et dispersione; idem de Influenza valet, quam quotidie observare licet; gravissima haec est materia et ampliore tractatione digna.

Tan=

Tandem nullus epidemicorum morborum, qui quidem descripti sunt, Peste excepta, tam vehemens, tam rapax atque generi humano exitiosus esse videatur quam Cholera Indica. Unde ab aliis comparatur Morbo Sudanti, ab aliis Pesti, quae ut Thucydides memoriae prodidit Athenas vexavit. Sed quae supra de hoc malo dicta sunt, ea non sine horrore lecta esse mihi persuasum est. Quandam vero consolationem affert cogitatio, calamitatis istius theatrum ad terrarum partem esse restrictum, quae a patria nostra longe distat. At recens quidam auctor narrat, in Persia quoque, quae alias coeli serenitate laudatur, Choleram, misere grassari, unde ominatur, aliquando futurum esse, ut celebriores Europae urbes ingrediatur.

»DI, prohibete minas: DI talem avertite casum".

TANTUM.

POSITIONES MEDICI ARGUMENTI.

I.

Cordis ventriculi, in homine sano ad mortem usque, sunt ejusdem capacitatis.

II.

Causa primae respirationis infantis recens nati a mutationibus, quas subit circulatio, derivanda est.

III.

Quamvis ex ipsa cordis fabrica sequitur, illud primarium esse circulationis sanguinis organon, tamen non sufficere videtur ad sanguinem per totum corpus propellendum; hac vero in actione egregie adjuvatur ab arteriis, tunica musculari instructis.

IV.

IV.

Distinctio inter fibram latam et gracilem ad praxin est utilissima.

V.

In singulis morbis diaetae imprimis habenda est ratio, quae si neglecta fuerit, vel perverse instituta, optimorum saepe medicamentorum virtus eluditur.

VI.

Saburra primarum viarum non semper est causa morbi praesentis; sed saepe effectus illarum viarum, vel etiam totius corporis debilitatis, ideo in multis casibus solus usus medicamentorum tonicorum sufficit ad sanandum morbum gastricum.

VII.

Sanatio radicalis Hydroceles per injectionem alicujus liquidi convenienter stimulantis, post eductam primum per acum triquetram aquam contentam, videtur optime.

VIII.

VIII.

Paracenthesin in Ascite proprie dicto licet, plurimi tanquam noxiam vel saltem inutilem proscripserint hanc tamen omnibus aliis praeferendam remediis non raro esse, cum Ill. ZWIETENIO, aliisque summis in arte viris censemus.

IX.

Punctura vesicae in hypogastrio reliquis (ad peritonaeum scilicet, per intestinum rectum et vaginam) merito videtur praeferenda.

X.

Periculosa ac minime probanda videtur Obstetricantium nonnullorum consuetudo, qui mox post natum foetum arte solvere conantur placentam.

TYPIS J. G. LA LAU.

XII. *On the Minute Structure of the Leg-muscles of the Water-beetle.* *By* Edward Albert Schäfer. *Communicated by* Dr. Sharpey, *V.P.R.S.*

Received March 13,—Read April 3, 1873.

For the successful prosecution of the histological inquiry which forms the subject of the present communication, it is essential that the tissue to be investigated should be studied whilst still in the living condition, inasmuch as marked changes ensue very speedily after the death of the muscle, and still more speedily on the addition of reagents, even the so-called indifferent fluids, such as serum or ½ per cent. solution of common salt, being in this case inadmissible. The description, therefore, I have now to give is founded entirely on an examination of the living tissue.

I. *Appearance of Living Muscle in the state of rest.*

If we cut off a limb from one of the common large Water-beetles (*Dytiscus marginalis*), remove a portion of muscle from the upper part, quickly separating the fibres somewhat from one another, by means of needles, on a glass slip, cover it without addition, and examine the preparation so obtained with the aid of a very powerful immersion-objective (such as the No. 11 of Hartnack or the No. 3 of Zeiss), we find numerous muscular fibres presenting an appearance similar to that represented in Plate XXXIII. fig. 1.

The well-known transverse bands are conspicuously seen, consisting of broader dim* stripes (*a a*) alternating with narrower bright ones (*b b*), the latter exhibiting a transverse line of minute dots (*c*). These bands are now very generally admitted to represent disks composed of two entirely distinct substances, arranged in successive series with their planes at right angles to the axis of the fibre; and I shall, for convenience of description, adhere for the present to this notion, although, as I shall afterwards endeavour to show, the difference in appearance which they present may be accounted for otherwise than by regarding them as composed of different materials.

To proceed with my description. Each disk of dim substance appears pervaded throughout by a number of excessively fine rod-shaped particles of uniform diameter, and rather darker in appearance than the substance of the disk which they traverse. These particles are arranged closely and very regularly, with their axes in a direction more or less parallel to that of the fibre; they extend at either end into the neighbouring disks of bright substance, becoming somewhat less distinct as they pass

* I use the word "dim" because, in fact, in living muscle at rest no such thing as a *dark* stripe occurs; one part is only somewhat less bright than the other.

into this, and finally terminating near its middle in an enlarged knobbed extremity, which appears as a minute dark dot. Consequently each of the bodies we are now considering, and which from their form may be denominated *muscle-rods**, may be described as consisting of a cylindrical middle part or *shaft*, which is imbedded in the substance of the dim stripe, and of two enlarged extremities or *heads*, which are found near the middle of the bright stripe. It further follows that there are as many series of muscle-rods as disks of dim substance in the fibre. Moreover each rod of any one series corresponds exactly with one in the next following series, their enlarged extremities almost meeting in the middle of the bright substance; this arrangement causes the appearance of a double row of dots (*c*) running transversely across each bright stripe†.

It must be observed, however, that in such a preparation as is here spoken of, the appearance represented in the figure, although very common, is by no means the only one that presents itself. All the variations, however, that are met with are accompanied and, as will be hereafter shown, in all probability caused by variations either in the relative position or in the form of the muscle-rods. Thus we not unfrequently find fibres in which the rod-heads of contiguous series, instead of being in more or less close apposition in the middle of the bright disk, are separated by a distinct bright interval; this is more especially the case when the muscular fibre happens to be somewhat stretched.

Sometimes a greater or less number of the rods of neighbouring series are shifted abruptly upon the rest in a longitudinal direction, so much so that their heads may come to be opposite the middle of the shafts of the remainder (see fig. 1). In such cases the transverse striæ also become correspondingly shifted. This fact would of itself almost preclude the conception of the existence of continuous membranes extending across the fibre, an idea which has been largely prevalent of late years.

The variations which occur in the *form* of the muscle-rods are chiefly, if not entirely, dependent upon the relation in size which subsists between the shafts and the ends, these seeming to be in inverse ratio with one another. Thus the shafts are not unfrequently increased in length, the heads at the same time becoming smaller and closer to those of the next series, so that a double row of dots is no longer seen in the middle

* A word here seems due to explain why the use of the term "sarcous elements"—which was applied by Mr. Bowman ("On the Structure and Movements of Voluntary Muscle," Phil. Trans. 1840) to the minute particles of which he conceived a muscular fibre to be composed, and which has been very generally applied by subsequent observers, both here and on the Continent, to the rod-like bodies which are commonly described in the muscles of insects—has been omitted throughout the present communication. The reason is simply this—that the term is ordinarily understood to imply that the bodies to which it is applied form the essential contractile constituent of muscle, whereas it will be seen from what follows that this is probably not the case with the structures here denominated muscle-rods. It should, however, be distinctly understood that the latter term is employed to signify simply the *form*, without reference to the nature of the material of which the particles in question are composed.

† Compare Strickers, 'Handbuch der Gewebelehre,' p. 1225.

of the bright stripe, having become merged into a single dark transverse streak, having a granular look.

If we imagine this process to go on still further—that is to say, if the shafts go on increasing in size at the expense of the rod-heads until each muscle-rod is of uniform diameter throughout, the ends of the rods of different series being in close apposition, it may well be imagined (the smallness of the objects with which we have to deal being taken into consideration) that it will be extremely difficult to detect the points of junction between the rods of successive series. In this way the continuous longitudinal fibrillation which is often seen in the muscles of the Water-beetle may be accounted for. That each fibril, however, is not in reality continuous throughout the fibre, but consists of a succession of shorter units, the ends of which are in close apposition, is shown, not only by the phenomena which occur when such a muscular fibre is thrown into contraction, and which will be referred to further on, but also by the appearances presented when a portion of the fibre comes under observation in which these units are thrown into zigzag instead of lying in the same straight line, in which case the angles of the zigzag represent the points of junction of the muscle-rods.

It is worthy of note that in all fibres like that we are now considering (that is to say, all in which the rod-heads are of the same diameter as the shaft, so as no longer to appear as distinct objects), the bright transverse bands have entirely disappeared, and the substance between the rods is of a uniform appearance throughout.

II. *Appearance of Contracted Muscle.*

In contracted muscle (fig. 2, C) we observe, besides the general increase in thickness of the fibre and the approximation of the cross striæ, that the latter have become completely altered in character. Dark and light transverse stripes now appear, which are of nearly equal size: the former, instead of being merely dim as in the resting muscle, have a decidedly dark aspect; the light stripes, on the other hand, present a very bright appearance, without any indication of a row of dots, but with sometimes a faint longitudinal streaking.

In order to explain this difference between a fibre at rest and the same fibre in the contracted state, it is necessary to follow all the stages of the process. Owing to the extreme suddenness and rapidity with which the contraction supervenes, and the amount of displacement which immediately precedes and accompanies it, it becomes a matter of exceeding difficulty to follow the details of the process with the high powers which it is necessary to employ. However, it has occasionally happened to me to observe a contraction proceeding at a very much less rapid rate, and in such cases it was possible to make out the following changes:—

The first thing seen is that the bright transverse bands become approximated throughout the contracting portion (P), and with them the dark transverse lines in their middle, which, as previously shown, are made up of a double row of dots (rod-heads). As the contraction continues the rod-heads become larger, and by this means

are brought into close relation with the neighbouring ones, so that each double line of dots (c) no longer appears as such but as a single dark transverse band (c_I), which separates the bright stripe (b_I) into two distinct parts. As these dark transverse bands approach one another, their bright borders encroach more and more upon the dim stripe (a_I), until this becomes reduced to a mere line, and finally disappears altogether: so that in contracted (C), as compared with resting muscle, the broad dim stripes (a) are replaced by bright bands (b_{II}), the clear stripes (b) by dark bands (c_{II}), these last being the optical sections of the disks which are formed throughout the fibre by the close juxtaposition of the enlarged rod-heads; the shafts of the rods have become much finer than before, so as to be hardly perceptible as they cross the now bright transverse bands.

III. *Transverse Section.*

When a small portion of living muscle is quickly teazed out upon a slip of very thin glass, to which it remains adherent, and the glass is then inverted over a ring of putty on an object-slide, so that the preparation is enclosed in an atmosphere which is saturated with moisture (Stricker's moist chamber), we are sometimes fortunate enough, in examining it, to find one or more fibres which are bent upwards near the end, and of which consequently we get a view of the transverse optical section (fig. 3). Employing the No. 11 Hartnack we observe the following:—

The cross section of the fibre appears of a rounded or somewhat oval form, enclosed by a distinct contour line (section of the sarcolemma), and with a small granular mass in the centre (central protoplasm), which may be almost entirely occupied by one or more nuclei. The area of the section between the sarcolemma and the central protoplasm has a minutely punctuated character, this appearance being due to the presence of a number of minute specks scattered equally over the field; the intervals between them appear homogeneous, clear, and bright. This appearance is obtained to whatever depth in the fibre we focus the microscope. As far as can be made out, these specks correspond with the rods which are seen in longitudinal view. The substance in which they are imbedded is quite similar in aspect to that which composes the bright transverse disks (fig. 1, b); why the dim substance in which, in longitudinal view, the shafts of the rods appear to be imbedded is not seen, as least as such, in the transverse section will become evident when we have treated of the production of the cross striæ.

IV. Cohnheim's *Areas.*

If, in order to obtain the transverse view of a muscular fibre, we employ the method recommended by Cohnheim* (that is to say, if we make a cross section of the frozen muscle and examine it in a so-called indifferent fluid, such as the ¾ per cent. solution of salt), we sometimes obtain the appearance described by him of dim polygonal areas, bounded

* "Ueber den feineren Bau der quergestreiften Muskelfaser," Virch. Arch. Bd. xxxiv. (1865).

by and enclosed in a network of clear bright lines. It would seem probable, however, that these areas are due to the action of the saline solution; for, as KÖLLIKER* has pointed out, they do not occur if the section is examined fresh without addition. A fine punctuation has been described within COHNHEIM'S areas†; this is, however, better seen when the limits of the areas are less marked.

It is but seldom that I have been successful in obtaining COHNHEIM'S areas in sections of *Dytiscus*-muscle. On the other hand, it is not at all uncommon to find fibres the section of which presents the appearance of dark lines, with bright intervals, radiating from the central protoplasm (fig. 4). The lines are equidistant from one another, and now and then divide dichotomously as they proceed outwards towards the sarcolemma. The picture presented irresistibly brings to mind the appearance of a transverse section of an incisor tooth as seen with a low power. The addition of fluid is not necessary for the production of this appearance, as seems to be the case with the areas of COHNHEIM.

As regards an explanation of these appearances, I am inclined to think that the section becomes mapped out into areas of COHNHEIM owing to a change which takes place in the intermediate substance between the muscle-rods, whereby, instead of being evenly diffused, this tends to collect at definite lines in the fibre, the rods which are enclosed by these becoming on this account more closely grouped, so as eventually to be no longer separately distinguishable.

The radiated appearance above described I was at one time inclined to explain in a similar manner; it may, however, be due to a slight inclination of the muscle-rods towards the axis of the fibre; in this manner they would appear to overlap one another, and so produce the effect of radiating lines.

V. *Ground-substance of Muscle—Cause of the Cross Striæ.*

The muscle-rods do not form by their agglomeration the muscular fibre, but are distinctly seen to be imbedded in a *ground-substance*, the characters of which we must now discuss.

This substance appears, as a rule, in longitudinal view not homogeneous, but, as before mentioned, to consist of alternating disks composed of two distinct materials, of which the one in which the heads of the muscle-rods lie is bright and clear, whereas that which contains their shafts is dim. The fact that the bright transverse bands are often seen to present a slight bulging opposite each of the rod-heads, and that when the latter become of the same diameter as the shaft (so as to be no longer seen as distinct objects) the bright bands also entirely disappear, would seem to show that the bright appearance is an optical effect produced by the presence of the globular heads.

That such an explanation is a possible one is shown by the following experiment:—

A strong solution of gelatine is taken, and having been rendered fluid by heat, a few drops of oil are added and the mixture is thoroughly shaken for a few minutes. By

* "Ueber die COHNHEIM'SCHEN Felder der Muskel-Querschnitte," Zeitschr. f. wiss. Zool. Band xvi. (1866).

† KÖLLIKER, *loc. cit.* ENGELMANN, "Mikroskopische Untersuchungen über die quergestreifte Muskelsubstanz," PFLÜGER'S Archiv, Jan. 1873.

this means the oil becomes suspended in the gelatine in a state of extremely minute subdivision. If, after the mass has congealed, we make a thin section from the middle with a razor, and in the section so obtained examine the minute oil-globules with a high power, they are seen as dark dots each surrounded with a bright halo *. If we happen to come across several such little oil-globules, arranged in a row close to one another, we obtain the appearance of a line of dots in the centre of a bright band.

The bearing of this simple experiment upon the production of the well-known cross striæ of muscle is obvious. For in a muscular fibre there are regularly arranged rows of minute spheroids (the globular rod-heads), the optical effect of which may be conceived to be quite similar to that of the minute oil-globules in our experiment, viz. to make the substance in which they are imbedded appear brighter in their immediate neighbourhood than it would otherwise be; by this means we obtain the appearance of the bright bands crossing the ground-substance, which have been described by all previous observers, with the exception of HEPPNER† (with whom DÖNITZ‡ would seem to agree in this respect), as constituted by a distinct substance.

It is further to be noted that the neck of each muscle-rod, the part where the head joins the shaft, is comparatively indistinct; this is due to the optical effect produced by the proximity of the globular head, and is contrary to what one would be led to expect if we assume this part of the rod to be imbedded in a clearer substance than the rest, for in such a case it would stand out the darker by the contrast. To this it is probably owing that previous observers have very generally failed in noticing the connexion of the row of dots with the rods.

The appearance of a transverse section is corroborative of the view here taken of the production of the bright bands; for in this case the dots are seen sufficiently close together for the optical effect produced upon the ground-substance by any one of them to be merged into that of the neighbouring ones, so that the intermediate substance appears uniformly bright.

The close relation subsisting between the rows of rod-heads and their bright borders is also seen when a muscle contracts, the movements of the one proceeding *pari passu* with those of the other.

A further indication that the whole of the ground-substance is of the same nature is to be found in the fact that, as will immediately be shown, it exhibits towards polarized light a similar behaviour throughout.

In the state of rest this ground-substance pervades the whole muscular fibre; in con-

* This appearance occurs both when the globules are in focus and also when they are slightly out of the focus; the surrounding brightness may be sometimes seen to be pretty sharply bounded by a margin, which is dimmer than the rest of the field. I am inclined to believe this to be an effect due to the interference between the rays of light which are reflected from the surface of the globule and those which are refracted through its substance. Its bearing upon certain appearances sometimes observed in muscular fibres will be noticed later on.

† "Ueber ein eigenthümliches Verhalten der quergestreiften Muskelfaser," SCHULTZE's Archiv, Band v. (1869).

‡ "Beiträge z. Kenntniss d. quergestr. Muskelf.," REICHERT und DU BOIS-REYMOND's Archiv, 1871.

traction, however, it seems to tend more towards the middle of the muscle-rods between their shafts, thus producing bulgings at the exterior of the fibre opposite these.

VI. *Appearances under Polarized Light.*

Although at first sight it may seem an easy matter to determine which parts of a muscular fibre are singly and which doubly refracting, yet, in fact (owing no doubt principally to the complex optical conditions which are produced by the heterogeneity of the structures through which the light has to pass), there is hardly any subject in histology in which greater difficulty occurs in arriving at a correct result. Accordingly scarcely any two observers who have carefully investigated living muscular fibre with this object have arrived at precisely the same conclusion. One of the chief difficulties is that of obtaining the muscular fibres in a sufficiently isolated state; for the addition of any fluid is quite inadmissible, and without such addition isolation of the individual fibres is liable to be accompanied by desiccation and loss of the normal structural appearances. Of course the presence of other fibres under or over the particular one we are examining may considerably complicate our observations.

Having fully experienced the difficulties of this part of the investigation, I have taken all the more pains to arrive at a trustworthy result, and therefore feel the less diffidence in stating my own conclusions, although they differ materially from those of other observers, with the partial exception perhaps of HEPPNER.

The method adopted has been to make the preparation upon a cover-glass, and to enclose it in a moist chamber in the manner already explained. In this way all possibility of pressure is avoided, and fibres are frequently obtained partially isolated from the rest and perfectly living and contractile. For the purpose of illumination, the oxycalcium light has been employed. For observing the optical conditions, as well as other phenomena, of contracting muscle, I have found it a good plan to pass into the moist chamber (whilst a fibre is under observation) air containing a trace of alcohol vapour. HARTNACK'S polarization-apparatus was used throughout.

The opinion, then, that I have been led to form, by a careful comparison of the appearances presented by muscular fibres in the states respectively of rest and of contraction, when placed between crossed Nicols, and with their axes at an angle of about 45° with the principal plane of either prism, may be shortly stated as follows:— Leaving out of consideration the sarcolemma, nuclei, &c., *the whole of the proper substance of a muscular fibre is anisotropous, with the exception of the* structures here designated *muscle-rods, which are isotropous.*

If we observe under the above conditions a living muscular fibre in the state of rest, the whole fibre appears illuminated on the dark field; and in consequence of this illumination we are able to make out the structural points (such, for example, as the presence of muscle-rods) almost as well as when it is illuminated by ordinary light. The rods are clearly distinguishable as dim streaks on the bright ground of the fibre, the heads giving the appearance, by their contiguity, of a single or double dark dotted

line. It may be objected that if the rods were isotropous they would stand out as *black* markings on the bright ground: but this does not necessarily follow; for since they are surrounded by, and imbedded in, the anisotropous substance, any rays which reach them from the lower prism must of necessity pass through this substance, and thus be made available for illumination.

In the contracted fibre the conditions are different; for in this case the heads of the isotropous rods are enlarged and in close contiguity, so that there is no perceptible amount of anisotropous ground-substance between them; and this being the case throughout the thickness of the fibre, we get a composite disk of isotropous substance produced, which remains dark between crossed Nicols. On the other hand, the anisotropous substance has now become collected between the shafts of the rods, disks of anisotropous substance being thus formed, which alternate and nearly correspond in size with those of isotropous. Consequently we have the effect produced of a series of illuminated stripes with dark intervals. The isotropous shafts of the muscle-rods, which are present in the former, do not stand out as dark streaks, for the same reason as that just stated in the consideration of the muscular fibre in the state of rest.

HEPPNER* has given a somewhat similar account to that here given of the appearance of muscle under polarized light. He describes a muscular fibre as consisting of only two substances, which he terms respectively *Hauptsubstanz* and *Zwischensubstanz*, which are disposed in alternating disks. Those of the latter substance he considers to be represented by the dark granular line in the centre of the bright bands; all the rest is *Hauptsubstanz*. The latter, according to him, is anisotropous, the former isotropous. Since the granular line referred to obviously corresponds with the line formed by the contiguous heads of the muscle-rods, it will be seen that HEPPNER'S account, so far as the mere description goes, very nearly agrees with that given by me.

An entire corroboration of the statements above given of the appearance of resting muscle under polarized light has turned up quite unexpectedly in a paper by Dr. F. MERKEL†, which has unfortunately only been in my hands a day or two, in which he makes the following statement (p. 294):—

"In a muscular fibre at rest, viewed under crossed Nicols, the contractile substance and the terminal disks appear bright and clear; the intermediate substance on the other hand so delicately (*exquisit*) singly refracting, that, when the field is completely darkened, there is no trace of it to be seen: the doubly refracting parts lie apparently immediately in contact with one another."

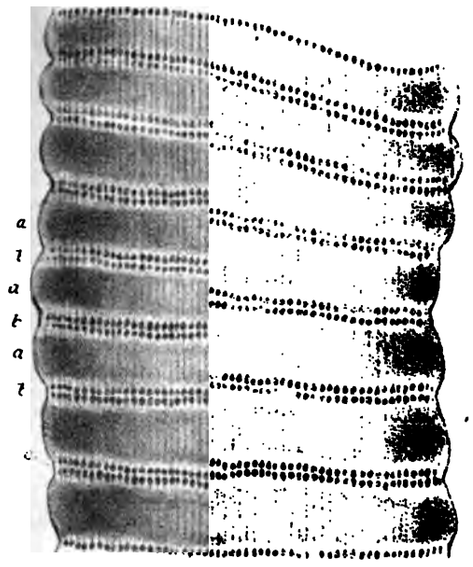
Putting aside MERKEL'S peculiar nomenclature of the parts which, according to his view, compose the substance of the muscle, it is clear that the appearance seen by him indicates that the whole fibre remains bright under crossed Nicols.

Further, I may adduce statements of Prof. BRÜCKE, whose well-known views as to the effect of muscular fibres upon polarized light are entirely different from those here

* *Loc. cit.*

† "Der Contractionsvorgang im polarisirten Licht," SCHULTZE'S Archiv, Band ix. (Jan. 1873).

1



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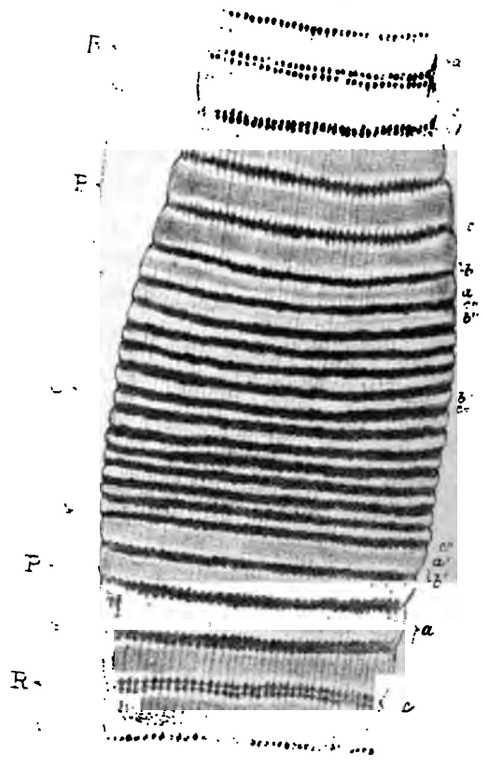

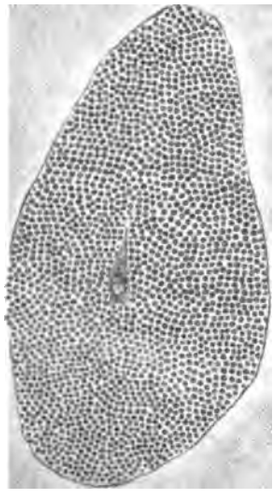

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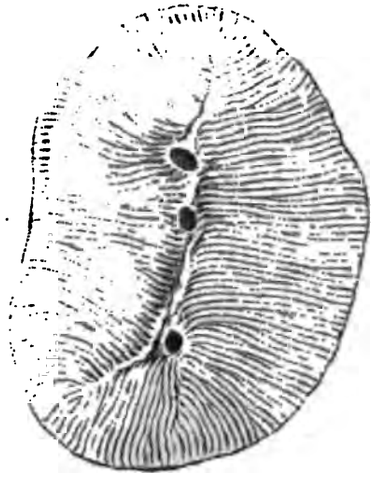

advocated, in support of the accuracy of the description I have given as to the whole of the muscular fibre in a state of rest appearing doubly refracting. BRÜCKE states, in effect, that, in the muscles of water-beetles in the living contractile state, he has but rarely been able to convince himself of the existence of an isotropous substance, that it never is so clearly seen as in dead muscle, but even here may be missed altogether. Very often so little isotropous substance appears as to be only represented in the resting muscle by a row of points, which form coherent stripes only during contraction. BRÜCKE remarks that this condition is probably the normal one during life, since he has most frequently come across it in perfectly fresh living muscle*. It is not difficult to identify BRÜCKE'S isotropous substance, which he also terms *Zwischensubstanz*, with the heads of the isotropous muscle-rods above described. But it may be asked, How comes it that in dead muscular fibres, especially if they have been placed in alcohol and subsequently mounted in Canada balsam or dammar-varnish, even though apparently fully extended, we so often observe broad alternating stripes of anisotropous and isotropous substance? To this I would answer that, although these fibres are not actually shortened, yet the elements composing them have tended to assume the condition that ordinarily accompanies contraction of the fibre (see below). And this opinion is fully confirmed by BRÜCKE'S statement†, that the isotropous disks are always broadest in such fibres as have been prevented from shortening at the time of death. It is, in fact, as if we took a fibre that had become fixed at death in the contracted state and mechanically stretched it out to its original length; in which case we may readily conceive the anisotropous and isotropous disks which are present in that state of the fibre to be equally stretched out.

And here I am tempted to offer a conjecture respecting the probable changes which take place during the contraction of muscle in the disposition of the structures which I have endeavoured to describe.

It is conceivable that the anisotropous ground-substance is the true contractile part of the fibre, and that it is allied in nature to ordinary protoplasm, but without the granular character commonly met with in the latter‡. The muscle-rods may be imagined to be composed of a labile, and at the same time elastic substance of semifluid consistence, possessed of considerable refracting power on light, and in all probability devoid of vital contractility.

* "Untersuchungen über den Bau der Muskelfasern mit Hülfe des polarisirten Lichtes," Wiener Denkschriften, xv. p. 79.

† *Loc. cit.* p. 80.

‡ Since the above was written my attention has been drawn to a paper by M. SCHULTZE (REICH. und DU BOIS-REYMOND'S Archiv, 1861), in which that author gives it as his opinion that the substance between the rod-shaped sarcous elements is the remains of the unaltered protoplasm of the embryonal muscle-cell. He would appear, however, to ascribe to it rather a nutrient than a contractile function, still looking upon these as the active elements of the fibre.

When a portion of muscle is called into activity, the contractile substance, or at least that portion of it which is between the *shafts* of the rods, shortens in the direction of the axis of the fibre, swelling out correspondingly in the lateral direction; the rods consequently become compressed in the centre, so that the substance of which they are composed tends to accumulate towards the ends. But these become also enlarged in another way; for the effect of the shortening of the fibre would be, first to press the heads of those in adjacent series against one another, and then, by a continuation of this process, to force them down upon their own shafts, encroaching upon the substance of these and becoming larger at their expense. The change of form may be most aptly compared to that which happens when the end of a thread of glass is put into a flame, the glass as it softens running up into a spheroid.

When the contraction ceases all the processes are reversed: it is possible that elasticity of the muscle-rods is an agent in restoring the fibre to its original length.

To recapitulate:—The general result of my investigations upon muscular fibre in the living state has been to induce me to regard the less strongly refracting intermediate substance which pervades the whole fibre as the contractile, irritable, and consequently essential part of the muscle, whereas the more refracting substance (which, as a rule, in the leg-muscles of *Dytiscus* appears in the form of distinct rod-shaped particles regularly arranged, but unconnected with one another) is, I think, to be regarded as performing a passive function only, and consequently as unessential to the idea of a muscular fibre, so far as its function of contractility is concerned. It is possible that this substance is analogous to that of which the granules ordinarily found in protoplasm are composed, being, however, in the case of striped muscle, for some reason at present unknown to us, arranged in a definite manner. That the ground-substance of muscle is doubly refracting, whereas ordinary protoplasm, such as that of which the pale corpuscles of the blood are composed, is not, cannot be taken as a proof of dissimilarity in nature; for, as is well known, the substance of which the cells of plain muscular fibre is made up (the protoplasmic nature of which few, I imagine, would be prepared to deny) is also doubly refracting. And since, according to the view here adopted, the more refracting substance is to be regarded as the non-essential part of the fibre, we must not be surprised if differences occur in the mode of its arrangement in the muscles of different animals, or even in different muscles of the same animal. In other words, it does not seem imperative that a typical structure should be selected to which all striped muscles must necessarily exactly conform; but, on the contrary, differences in the arrangement of the non-essential elements may, and undoubtedly do, occur without corresponding differences in the essential functional activity of the fibres.

A great deal has been written within the last few years with regard to the structure of striped muscular fibre. Previously to 1868 the views of BOWMAN, as modified by ROLLETT, were very generally accepted as affording an explanation of most of the appear-

ances observed; some histologists, however, *e. g.* KÖLLIKER, were disposed to regard fibrils extending from one end of the fibre to the other as the ultimate elements of the muscle. In the year mentioned, KRAUSE, in a paper on the subject*, drew particular attention to the transverse line in the centre of the bright band, and, looking upon this as the optical section of a fine membrane stretched transversely across the fibre, described the latter as being divided into a number of flat compartments (*Muskelfächer*), each containing a disk of solid substance in the centre, separated from the membrane above and below by fluid. At the same time, taking the fine lines bounding the polygonal areas described by COHNHEIM in transverse sections to be the optical section of similar membranes running parallel with the axis of the fibre, and of course meeting the others perpendicularly, he described the flat compartments as thus subdivided into a number of muscle-boxes (*Muskelkästchen*), each of them bounded by membranes both at the ends (bases) and sides, each base-membrane being common to two contiguous muscle-boxes. Each muscle-box, he considered, is almost filled by a portion of the dim substance (muscle-prism), this being separated from the base-membranes by fluid. Subsequently KRAUSE described the muscle-prisms as consisting each of a bundle of more minute particles, which he termed muscle-rods (*Muskelstäbchen*). [The transverse line bisecting the clear stripe was known long previously to KRAUSE's paper on the subject. It was described by BUSK and HUXLEY† as occurring in the muscles of insects; and since they observed with marvellous correctness that it was not so much a continuous line as a succession of contiguous dots, it was supposed by them to be due to the existence of a row of minute sarcous elements interpolated between the rows of larger ones, which were regarded as forming the darker stripes of the fibre. The rod-like character of the so-called sarcous elements had also been long known: it was distinctly figured by BRÜCKE; and SHARPEY had more lately drawn attention to the close connexion which exists between these rod-shaped particles and the minute dots composing the transverse line, only just falling short of tracing the one into the other—this, too, both in the muscles of insects and in human muscle‡.] HENSEN §, writing about the same time as KRAUSE, gave a somewhat similar account of the structure of muscle, also drawing especial attention to the apparent membrane bisecting the light stripe; as regards some points, however, his account was en irely at variance with that given by KRAUSE.

The next contribution to the subject of any importance was that of HEPPNER‖, who employed the still living contractile fibres of *Hydrophilus piceus*. He assumed the dark transverse line in the middle of the clear stripe to represent a *continuous disk* composed of a substance (*Zwischensubstanz*) possessing a *lower* index of refraction than the rest of the fibre, and endeavoured to show, by the assistance of a diagram, that the bright

* "Ueber den Bau der quergestreiften Muskelfaser," Zeitschr. f. rat. Med. xxiii.

† KÖLLIKER's 'Manual of Human Histology.' Sydenham Society's Translation, 1853.

‡ QUAIN's 'Anatomy,' 7th ed. 1867, vol. i. p. cxix.

§ Arbeiten aus dem Kieler physiologischen Institut, 1868.

‖ "Ueber ein eigenthümliches optisches Verhalten der quergestreiften Muskelfaser," SCHULTZE's Archiv, v. 1869.

appearance on each side of it is produced by a total reflection of the rays of light from its surfaces—considering, from the fact of its similar behaviour under crossed Nicols, the substance forming the clear stripe to be similar in nature to the rest of the muscle-substance, with the exception of the *Zwischensubstanz* before mentioned. As a further indication that the bright bands are due to such an optical effect as he described, HEPPNER remarked that their position became altered according as the mirror was inclined or the stage rotated.

Quite recently three important contributions to the study of the structure of striped muscular fibre have appeared; those, namely, by FLÖGEL*, MERKEL†, and ENGELMANN‡ respectively. MERKEL, studying the fibres of the Arthropoda, principally by means of alcohol preparations, finds the transverse line of KRAUSE to be not simple, as believed by the latter, but in reality to be made up of two lines representing juxtaposed membranes (terminal disks or *Endscheiben*), best seen when the fibre is stretched. He further describes an exceedingly indistinct disk (*Mittelscheibe*) in the middle of the dim stripe of the muscle, not always visible, and often only represented by a somewhat lighter appearance of that stripe at this part. The contractile substance of the muscle he describes as being, in the state of rest, arranged on either side of this median disk, with a clear fluid separating it from the terminal disks above and below. The enclosure of each muscle-element is completed at the sides by a lateral membrane. In contraction of the muscle MERKEL describes the contractile substance as at first becoming diffused throughout the muscle-element, and finally becoming collected in the vicinity of the terminal disks. By what mechanism such locomotion is capable of producing shortening of the muscle is not explained§.

FLÖGEL, who for the most part employed muscle of *Trombidium* which had been treated with osmic acid, describes a fibre as divided into compartments, similar to those described by KRAUSE, by means of transverse partitions (*Querwände*), which, however, he believes to be formed by the juxtaposition of granules interpolated at regular intervals in the course of the fibrils, which latter extend from end to end of the fibre, imbedded in a ground-substance which is probably of a fluid nature. In the median portion of each muscle-compartment these fibrils, if I understand FLÖGEL'S meaning aright, are more marked (*Säulen*) than near the transverse partitions, in the immediate neighbourhood of which the substance is clear and homogeneous, but contains both above and below each transverse partition a row of minute granules (granule-layer); and since it may sometimes be seen that each granule lies in the same longitudinal line as one of the minute columns in the central part, the two are probably parts of the same fibril.

* "Ueber die quergestr. Muskeln der Milben," SCHULTZE'S Archiv, viii. Nov. 1871.

† "Der quergestreifte Muskel," SCHULTZE'S Archiv, viii. Jan. 1872.

‡ "Mikroskop. Untersuchungen über die quergestr. Muskelsubstanz," PFLÜGER'S Archiv, vii. Jan. 1873.

§ It is but fair to add that MERKEL'S results are principally based upon observations on the so-called fibrils of the thorax of insects; and these present in many respects a structure entirely different from that met with in the muscles of the legs, this apparent difference being due to a different arrangement of the non-essential substance (compare p. 438).

A view of muscular structure still more complicated has very lately been set forth by ENGELMANN in his exceedingly elaborate article on the subject. ENGELMANN enumerates no less than ten distinct layers as included in each muscle-segment or compartment (*Muskelfach* of KRAUSE). Each of the segments, according to him, is bounded at each end by a thin but well-marked layer (*Zwischenscheibe*), often appearing granular, and which is common to two contiguous segments. This corresponds with the transverse partition of FLÖGEL. Passing inwards from these we come first upon a clear layer, then a somewhat dark layer (*Nebenscheibe*), which often appears to consist of a row of granules (the granule-layer of FLÖGEL), then upon another clear layer, and finally, in the centre of the muscle-compartment, a broad dim layer (*Querscheibe*), the middle portion of which appears somewhat less dim than the rest (*Mittelscheibe*). Each of these layers is described with great minuteness by ENGELMANN. He does not, however, maintain that they are all to be made out in every case, but only in those instances in which a considerable interval separates the stripes. He further asserts that the *transverse* markings are the only ones which are met with in the living fibre in its normal condition; and in proof of this he states that the transverse disks appear completely homogeneous when viewed *in situ* in the living animal (as, for instance, in minute transparent Crustacea), exhibiting, therefore, no trace of longitudinal striation. The pallisade-like arrangement of the elements which has been described is, he maintains, due to a change which occurs at the moment of death of the fibre, those portions of a fibre in which individual rods have become visible being, according to him, no longer irritable. To explain these so frequent appearances, ENGELMANN assumes the muscular substance to be wholly composed of closely compressed, elongate, prismatic elements extending the whole length of the fibre, and exhibiting at regular intervals differences in chemical and physical properties, producing thus the several transverse layers. He conceives that at the moment of death of the fibre a coagulation and shrinking of these elements take place, accompanied by expression of fluid; and in this way accounts for the fibrillar and granular character which the transverse disks commonly exhibit.

Of the accounts given by the various authors with regard to the behaviour of muscle under polarized light, I have thought it best to say nothing in this place—partly on account of the irreconcilable differences of opinion on the subject, partly because the question has already been very fully discussed in a preceding page.

It only remains for me briefly to point out the parts which, in the several accounts here quoted, seem to correspond with those enumerated by me in describing the appearance of the living muscle of *Dytiscus*. But, first, I would take the opportunity of expressing my unqualified dissent from the positive assertions of ENGELMANN, above noticed, with regard to the homogeneous appearance of muscular fibre in the living state, at all events so far as *Dytiscus*-muscle is concerned. I would affirm, on the contrary, that *however quickly* the preparation is made (and the quicker the better), we find numerous muscular fibres exhibiting the structure I have described, in which the muscle-rods appear with perfect distinctness throughout the whole extent of the fibre,

and that such fibres are capable of repeatedly undergoing the most complete spontaneous contraction: indeed after the death of the fibre the distinctness of the picture becomes always very much impaired, and often the structural appearances become entirely obliterated. Further, I may remark that since reading ENGELMANN'S article I have taken what opportunities offered of examining the muscles of minute aquatic Crustacea and insects whilst still in the living body, and as a result of such examination may state that, in spite of the difficulties to observation offered by the presence of the chitinous integument and the small size of the muscular elements, there is no great difficulty, with a good immersion-glass, in seeing that they possess an apparent longitudinal fibrillation. If further proof were needed, it is to be found in an exceedingly interesting paper by Professor WAGENER*, in which the appearances observable in the muscles of the *Corethra*-larva in the living state are fully detailed. But to return to our subject.

The transverse membrane of KRAUSE and the narrow disk of intermediate substance (*Zwischensubstanz*) of HEPPNER would seem to be referable to the heads of two contiguous series of muscle-rods, which, as before stated, often meet in the middle of the clear stripe. The terminal disks of MERKEL, the granule-layers of FLÖGEL, and the *Nebenscheiben* of ENGELMANN are also, I think, to be referred to the same structures, which are by these observers correctly differentiated into two rows. The *Stäbchen* of KRAUSE and ENGELMANN and the *Säulen* of FLÖGEL would appear to correspond with the shafts of the muscle-rods of my description. There remain the *Mittelscheibe* of MERKEL and others, and the line between each two muscle-series, which is to be seen only in very extended conditions of the fibre (*Querwand*, FLÖGEL; *Zwischenscheibe*, ENGELMANN). To explain these appearances, it is necessary to revert to what has been said with regard to the minute oil-globules in the experiment before mentioned†. It was there noted that the bright halo around each oil-globule is often seen to be bounded by a marginal line rather darker than the rest of the field, and probably to be explained by interference. The granules in muscle (rod-heads) must each have a similar effect upon the light; and since they are disposed in rows, so that their bright haloes coalesce into bright bands, these darker margins must similarly coalesce into dim bands. Consequently the edges of the broad dim stripe (*Querscheibe*, Plate XXXIII. fig. 1, *a*) of muscle will be caused to appear somewhat darker‡ than the central part (*e*), which latter has been for this reason taken for a distinct layer (*Mittelscheibe*). Of course in the case of a muscular fibre all these effects are very much more marked than if we had to deal with a single series of granules, since other rows which are somewhat out of focus contribute to increase the result §.

* "Ueber einige Erscheinungen an den Muskeln lebender Thiere," Sitzungsb. d. Gesellsch. z. Beförderung der gesammten Naturwissenschaften zu Marburg, No. 8, August 1872.

† See footnote, page 434.

‡ The contrast with the bright band would probably tend to enhance this effect.

§ When a very strong light is employed coloured fringes are often visible on the confines of the dim and clear stripes, and doubtless result from such interference effects as I have indicated.

The *Querwand* or *Zwischenscheibe* may probably be similarly explained; for where it appears the rows of rod-heads of adjacent series are so drawn away from one another by the extension of the fibre that their bright borders are no longer blended, and a dim line (in all probability rendered darker by interference) comes into view between them. The argument in favour of the existence of a continuous membrane across the fibre, drawn from the fact that indentations of the sarcolemma pretty constantly occur at this place, loses its weight when we reflect upon the extreme delicacy of the sarcolemma, and the necessity which must exist for it to follow any changes of shape which may occur in the enclosed substance.

Description of the Plate.

PLATE XXXIII.

Fig. 1. Portion of a muscular fibre of *Dytiscus* in the state of rest.

a a a. Dim stripes.

b b b. Bright stripes.

c. Double dotted line in bright stripe formed by the heads of

d. The muscle-rods.

Fig. 2. Muscular fibre undergoing contraction.

R R. Portions still at rest.

P P. Contraction proceeding.

C. Contracted portion.

$a\ a_{I}$. Dim stripes.

$b\ b_{I}\ b_{II}$. Bright stripes.

$c\ c_{I}\ c_{II}$. Lines formed by rod-heads.

Fig. 3. Transverse section of muscular fibre of *Dytiscus*. The irregular patch in the centre, containing a round nucleus, is the so-called central protoplasm.

Fig. 4. Transverse section of muscular fibre of Water-beetle, made whilst frozen, showing the appearance of radiating lines described in the text.

6.

To Jabez Hogg Esq:
from Wm Simpson.
30th April. 1880

III. BUDDHIST ARCHITECTURE IN THE JELLALABAD VALLEY.

By WILLIAM SIMPSON, F.R.G.S. Read. 12. Jan. 1880.
1223. 1279

THE extension of our knowledge of Indian Architecture to the region of the Indus has been productive of important results. The space of time is but short since we were in all but complete ignorance of the ancient remains of this part of the world. Twenty years ago scarcely any materials existed from which an idea could be formed of the styles of architecture that had been practised there in the past. Now we have considerable data upon which to work, and already some valuable deductions have been made. Standing out prominently among the points arrived at is the fact of a Greek influence having filtered through the Bactrian provinces to the Indus, which it crossed and penetrated as far as the Punjab and Cashmere—how much further is a point not yet reached. This fact is of very great importance as bearing on Indian architecture, but it is at the same time of equal importance to the history of Greek art. We already knew the vitality which the architecture of Greece possessed, and which carried it to distant regions at an early date; still we have a further proof, in this now accepted theory, of its remarkable power, and that like the Macedonian hero, it carried its conquests beyond the Indus. Along with this we have another point now equally well established, and of high value to the art historian, which is, that previous to the Greek there was an influence brought from the Euphrates valley, most probably from ancient Persia; this not only crossed the Indus, but penetrated at least as far south into India as Karli on the west, and Buddha Gaya on the east. The bell-shaped capitals in the Karli Cave, and on the Buddhist lats, as well as in the sculptures at Bhilsa, and other places, had often been identified with the well-known Persepolitan examples, but all doubt now ceases regarding their source; that point having been made clear from the details found in connection with them on the western bank of the Indus and in Afghanistan.

It has been very common for writers to affirm that all remarkable things in the past had their origin in India. This is now exploded. All inquiries seem to tend to the conclusion that religions, conquerors, ideas, art and architecture all crossed the Indus into India; with the exception of the Buddhist propaganda nothing ever went in the other direction. Perhaps no better illustration of this can be given than the invasion of India by the two styles of art just mentioned. Here we have reflected light on the history of the region, and we find light which is valuable as historical data, as well as being an addition to our knowledge of art.

The first suggestion of the existence of Greek art in the region of the Indus is in the account of Elphinstone's mission to Kabul. In 1808, while returning through the Punjab, the members of the mission visited the Manikyala Tope, and remarked the Greek character of some of its parts. Professor Wilson, who refers to this,* seems to discard the opinion, because, as he says, "it has been since fully proved the work of Indian artists."† In 1860 I visited this well-known monument and made sketches of it, and the result of doing so was to leave no doubt in my own mind as to the Greek origin of its details. On my return to

* *Ariana Antiqua*, p. 31.

† General Cunningham published, in 1848, a small work called "An Essay on the Arian Order of Architecture, as exhibited in the Temples of Kashmir"; therein the architecture of Cashmere is identified, in many of its details, with the Greek.

London in 1862 I read a Paper here on Indian architecture,* in which I stated that the capitals were Corinthian; I exhibited at the time the section of a frieze, and affirmed that it was sufficient in itself to establish the classical character of the architecture. The year following I visited Cashmere, and these conclusions of a Greek influence were confirmed by finding traces of Doric, and also of what I took to be Ionic, but of this last I did not at the time feel quite so certain. References to these will be found in my Paper above referred to. In the Lahore Museum there is the base of a column found in 1864 at Shah-ki-dera, the site of the ancient Taxila, on the east side of the Indus, and it is so purely Greek that its character cannot be doubted. That these were not exceptional and isolated instances was at last fully established by the explorations in the Yuzufzai district, situated on the west bank of the Indus north-east of Peshawur. The explorations at Takht-i-Bahi, Jamal Garhi and other places in that region, which were carried on about ten years ago, resulted in the discovery of Corinthian capitals which brought conviction home to everyone. Numerous sculptures were also found in which the pose of the figures, as well as the treatment of the drapery and other details, bore clear evidence of an influence from classic Greek sources. These sculptures are now in the Lahore Museum, and they form a unique collection in connection with this subject.

These details of progress all refer to ground within what was the British frontier before the present Afghan war began. Beyond the frontier our knowledge was almost a blank. Afghanistan has not been a favourite country for travellers; very few have visited it, and this is the reason why we possess such scanty materials regarding its architectural remains. Masson is about our only authority, and his explorations were made to procure coins. I have seen the excavations which he conducted in the Jellalabad valley, and he does not seem to have made a single effort in any case to bring the architecture to light. He had been in Afghanistan for some time before 1834, and remained there till the first Afghan war, hence he must have been about ten years in the country.† At that period little or nothing was known of Buddhist architecture, and the character of the mounds was evidently an enigma to him. His drawings are so small that no details can be made out from them. His works prove that he was a person of considerable ability, and the great quantity of coins which he collected were of the highest value as bearing on the ancient history of the region. I may say that previous to the present Afghan war our knowledge of Indian architecture did not extend beyond the extrance to the Khyber Pass. Being conscious that such was the case, the chance of obtaining information on the subject, however small it might be, was one of the inducements which led me to follow our troops in the campaign, and I think I can place before you sufficient materials by which knowledge on this subject will be extended as far at least as the limits of the Jellalabad valley.

I joined the head-quarters of General Sir Samuel Browne's force at Jamrood on the 20th of November, 1878. On the road to this place, about half way from Peshawur, I passed Hari Sing ke Boorj, where there are considerable remains, in the form of mounds, of the Buddhist period. The Fort of Jamrood is, I believe, built over the remains of an old tope; and General van Cortlandt, who superintended the construction of the fort in 1837, tells me that it was built over an ancient mound. Lieut. Bartram, R.E., gave me sketches of some mouldings of the old masonry which he found projecting at one place through the later walls of the Fort.

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* See the TRANSACTIONS, Sess. 1861-62, pp. 174-5.

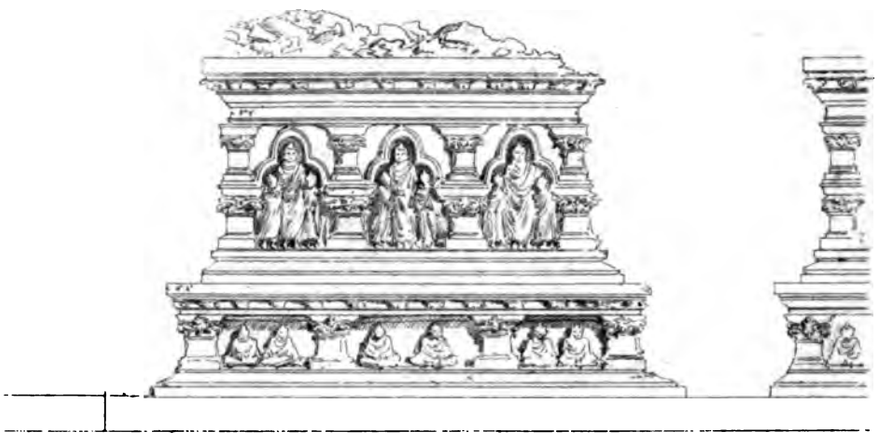
† Col. Yule states that Masson was little more than five years in Afghanistan.

to face page 39.

FIG. 1.

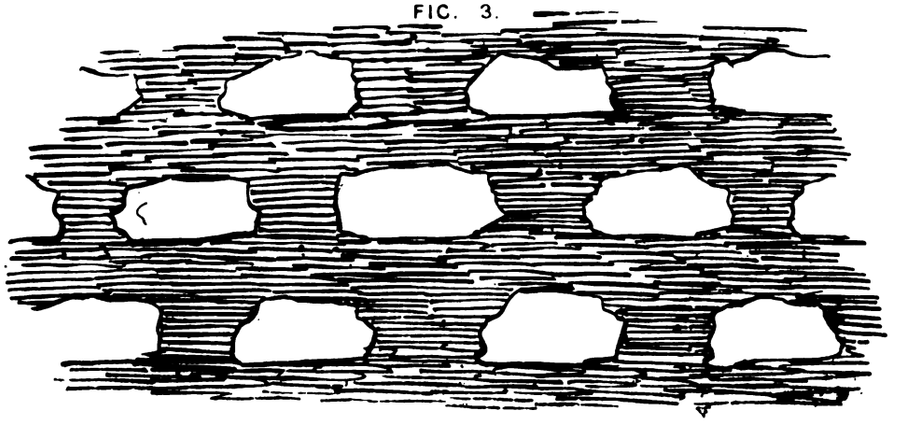
CORE OF CAPITAL.
BARABAT TOPE, JELLALABAD VALLEY.

FIG. 2.



BASES OF SMALL TOPE AT HADA NEAR JELLALABAD.

FIG. 3.



BUDDHIST MASONRY, NEAR JELLALABAD.

William Simpson

Photo-Lith^d by C. F. Kell Castle St Holborn, E.C.

On the morning of the 22nd November I climbed the steep ascent and entered the Fort of Ali Musjid with the General and his staff, and here for the first time I saw the peculiar kind of masonry which belongs to the Buddhist period in Afghanistan, and which I shall refer to as "Buddhist masonry." The part of the Fort which our guns had bombarded the day before was of late construction. The hill being partly isolated there is a long wall on its western side that our fire did not touch, and which is wholly of this Buddhist masonry. The character of this kind of building is so marked that it is easily recognized. Stones, more or less rudely squared, are placed at intervals, with slates built in between each stone; a continuous layer of slates is then made forming a course in itself, and on this is placed the next course of stones with slate between them again—the whole presenting the appearance of a diaper pattern.* What was the object of this peculiar kind of building is not at all clear. The only suggestion I can make is, that as earthquakes are not unknown in the region, it may have been adopted with a view to flexibility. I cannot say that this theory is a satisfactory one, but it is the only motive I can as yet suggest. There is an ample supply of slate in the mountains of Afghanistan, and this may have led to its use as a building material. The quantity of slate varies considerably in this Buddhist masonry, but it always forms by far the greater part of the superficies of the wall. In the Barabat Tope it is nearly all slate,† and I saw other walls of the same kind. At Chardeh there is a tope with only a small fragment of its masonry remaining, and in this the stones are neatly squared with no slate between; there is only a course of slate between each course of stone. This Buddhist masonry is found in the Yuzufzai country, but I have not heard of it on the east of the Indus, and I think it may be stated with confidence that this manner of building did not come from India. Sir Henry Rawlinson visited Ecbatana, in Northern Media, in 1838, and in describing its walls he says:—"The breadth of the wall is 12 feet, the outer facing being composed of hewn blocks of stone about 14 inches deep and 2 feet in length, alternating with thin stones laid edge-ways and perpendicularly between them; and the whole being fitted with extreme care and nicety."‡ I do not feel quite sure as to how these words ought to be understood, but they suggest a style of building wonderfully like the Buddhist masonry of Afghanistan. The mode of placing the thin stones between the larger ones may not have been precisely the same as that followed towards the Indus, and yet both may turn out to be only varieties of a masonry which was common to the whole region between where each is found. It was only the "outer facing" of the wall at Ecbatana which had this character. Sir Henry says that "the interior is filled up with huge unhewn blocks imbedded in a lime cement." It is the same with the Buddhist masonry, the outer surface only is built with it, the interior is formed of rude stones, often water-worn boulders, imbedded in mud, the whole forming a solid mass. These identities are very striking, and there is nothing improbable in the supposition that if such a mode of construction was common to the hill countries on the east of the Euphrates, where the material could be easily obtained, the style may have been carried as far as the Indus as early as the time of Darius, or at the date of the arrival of the Persian style of architecture in India. Careful inspection of ancient structures to the west and north of Kabul, if any exist, will be the only means of giving us safe data on this subject.

A peculiar manner of building does not necessarily change with the religion of the locality where it exists, and it is quite possible that the Buddhist masonry may not have altogether

* See pl. 1, fig. 3. † See pl. 1, fig. 1. ‡ Journ. Roy. Geogr. Soc., vol. x.

ceased with the downfall of Buddhism. Although recognizing this rule, yet I should be inclined to the opinion that the Mahomedans did not continue the style in the Jellalabad valley or the Khyber Pass, and hence I take it that the Buddhist wall in the Fort of Ali Musjid is as old as the Buddhist period. Whether it was originally a religious establishment or a fortified position is somewhat doubtful. At Lundi Khana there is an old fortified place, all of Buddhist masonry, and in it there is no appearance of topes or viharas. It is high up above the Pass on a rocky height, perhaps 2000 feet above the road. The cliff is perpendicular on one side for about 400 or 500 feet, and a strong wall, nowhere less than 6 feet wide, runs along the steep slope on the other side, inclosing a narrow space all the way which is not over 30 feet wide at any part, and the greater part of it is not half of that width. There are the remains of a stair down the side of the cliff behind, where there are also some walls large enough to have formed a good house, and a communication existed to a small stream of water. There are the remains of a few houses on the crag above, but they are of the smallest dimensions, owing to the narrowness of the inclosed space. It is one of the most remarkable fortified places I have ever seen, thus to inclose for such a distance the topmost crags only of a high hill. I had some natives of the locality as guides on my visit, and I called the spot a "Buckra ke Killah," or Goat's Fort, a descriptive term which seemed to please them, and I repeat it here as it may convey some idea of this remarkable fortified eyrie. Its existence tends towards an assumption, which we need not reject, that even under the non-slaying teachings of Buddhism, there were dangers existing to life and property requiring places of defence, and it is quite possible that Ali Musjid was one of them. It is the real entrance to the gorge of the Khyber on the Indian side, as Lundi Khana is towards Kabul; and a fort at each end to command the Pass is so highly probable that we may almost take it for granted. Some small topes, as well as a fragment of Buddhist wall, were come upon on the ascent to Ali Musjid, but the existence of these are not incompatible with the theory that the walls on the summit belonged to a fortress. About half a mile lower down the Khyber stream, on a small hill overlooking it, were found the remains of a religious establishment, surrounded by a group of small topes of a very interesting character. These were explored by Mr. Beglar, of the Indian Archæological Department, and some very valuable details were brought to light. I have heard of other Buddhist remains near Ali Musjid, but I cannot speak of them as I have no details.

After passing the grand rocky gorge above Ali Musjid the Khyber Pass begins to open, and at Lalabeg it widens into a valley, with villages and flat cultivated land. It was when approaching this that I got the first sight of the Ishpola Tope. It stands on the summit of a mass of rock which projects into the valley, and our road passed close under it. The effect of this fine monument dominating over the plain, and surrounded with picturesque hills, is very striking. Its contrast with the mud villages of the present day tells as plainly as words could of a past when the country was in a flourishing condition, when there was wealth; and that art and architecture were then not unknown in the region. It may be stated here that, in the present day, Afghanistan has fallen low in these pursuits. Houses are formed of mud, and the carpentry of doors and windows is of the rudest description. I saw the ruins of a brick house at Jellalabad, but at present no structures seem to be built of this material. The walls of Jellalabad are all of mud, and the wooden gates would be sure of the first prize if it were

to be given for the worst kind of work. As for art there did not appear to be anything of the kind in the country. There are here and there a few Hindoos who make gold and silver ornaments, but their work is poor and of the coarsest character. I did not visit Ghuzni, where fine buildings have been erected since the Mahomedan period, but from Jamrood to Gundamuck there is not a vestige of architecture to be found dating since the worship of Buddha ceased. In the present day these attendants of civilization have simply become extinct, and have no existence even in their ruder forms. In such a country you can imagine the effect produced by the Ishpola Tope. I had no means of measuring it, but should say it could not be much less in size than the Manikyala Tope, which is nearly 130 feet in diameter, and to which it bears a closer resemblance than the topes in the Jellalabad valley. This results from the cylindrical portion of it being much less in height than those of the latter place. The dome is still nearly complete on the south side. It differs conspicuously from the Manikyala Tope in having a square base, which is one of the marked characteristics of the Jellalabad examples. This square base has 14 pilasters on each side. Three of the spaces between the pilasters are recesses in which I suppose there have been sitting figures of Buddha. At the north-east corner there is a retaining wall, which is a good specimen of Buddhist masonry, made to support the monument on that side, where the rocky surface is lower than in the other corner. The capitals of the pilasters are Corinthian. There are no pilasters on the circular part of the Tope. On my return from Gundamuck in June I made a second inspection of the remains, and found that some one had made excavations. The stair which led up to the top of the square base, was partly cleared; it approaches from the north. Round the lowest member of the base had also been exposed a continuous row of small sitting Buddhist figures about 18 in. high, placed so close that they touched each other. The remains of the vihara were quite distinct on the side of the hill behind, in some parts the walls stood a considerable height above the ground. In one or two places I noticed the circular courses of the masonry of small topes, one of which was about 6 feet in diameter. One of the villages near to the Tope is built on the remains of Buddhist walls, but what the place had formerly been it was impossible to determine.

At Lundi Khana there are remains with Buddhist masonry on each side of the Pass; and in the valley leading to Daka from Lundi Khana, which is generally included as part of the Khyber, there are other similar remains, but I was not able to inspect them sufficiently to be able to say what they are. Near Hazar-Nao, and close to Basawul there are isolated hills covered with fragments of walls and quantities of débris, which I have no doubt belonged to the Buddhist period. At Chardeh there is a prominent hill overlooking the plain, with the remains of a tope upon it. I went up in passing and made sketches of this place. The tope is only a rude mass of masonry, all its outer surface has fallen away, and I only saw one or two stones of the external surface remaining. These I have already referred to as one of the varieties of Buddhist masonry, the stones having been squared and touching each other on their perpendicular surfaces, but the courses are separated by a layer of slates between, which will be understood when I say it produces a streaked effect, instead of the diaper pattern of the usual Buddhist manner of construction. There are what I take to be the remains of the monastery on the north and south sides of the tope, and among those on the south I could distinguish the plan of some of the cells, small places not over 8 feet

square. The hill is so narrow on the summit that the base of the tope entirely covers it, and the buildings on the north had to be supported by a very high retaining wall, which is still in very good condition, and is, I should say, the finest specimen of Buddhist building I saw in Afghanistan. Here, as well as at Ishpola, I could see rude caves in the rocks around—those at Ishpola seemed to be natural recesses on the face of the rock under the tope, and were just the kind of places an Oriental ascetic would choose to live in. My notion was that they were older than the topes, and I venture the suggestion that the monasteries at these places may have resulted from the fame for sanctity acquired by some early resident giving a reputation to the spot. Ishpola is probably an old name, but Chardeh is Persian, meaning the "Four Villages," the original Buddhist name being lost—this I am sorry to say is what has occurred with almost all the Buddhist places in Afghanistan. It is much to be regretted, for names often give a clue to the character of remains, and now that we have the travels of the Chinese pilgrims to refer to, the names would have been invaluable as a means of identification with the localities described by them.

Although much obliterated, the old path up to the Chardeh hill is still visible, and at its foot there is the ziarat of Peer Kamil Baba: that is, the tomb of a Mahomedan saint, it being one of the most marked customs of the Mahomedans of Afghanistan to go to the tombs of their saintly men for purposes of prayer. These shrines are made of mud, often decorated with white pebbles, and their existence can be detected from a distance by a long pole and a piece of coloured cloth on the end of it. I was struck in this case to see the Mahomedan to-day saying his prayers at a tomb, with the old tope or relic shrine above, where the followers of Buddha performed their devotions, showing, though new teachers may appear, and creeds may differ, that "Tomb-worship," one of the oldest forms of religion, remains the same. I also noticed here the beautiful view from the hill on which this monastery stood, and I found it the same with the sites of monasteries in the Jellalabad valley: they were all on commanding eminences overlooking the level plain, and giving a pleasant look out on the mountains around.

The march from Chardeh brought us to Ali Bogan, at the eastern end of the Jellalabad valley, and the next day, the 20th December, we went on to Jellalabad, remaining there in camp till the 12th April. It was the long stay at that place, resulting from a lull in the operations, which enabled me to visit nearly all the remains, and at the same time to carry on explorations at one or two of them.

The valley is about nineteen miles from east to west, a lateral group of hills at Girdi Kas separating it from the plain of Chardeh on the east; the Sia Koh Range forming its western barriers, to the north-west of which is the district of Lughman. Away to the south is the Suffaid Koh Range, with its long line of snowy peaks, and on the north is the remarkable and beautiful mountain, called the Ram Koond, which was white on its summit during the most of our stay. If the Jellalabad valley had more trees and cultivation, which I believe was its condition in the days when Buddha was worshipped there, it would be one of the loveliest spots on earth. The quantity of Buddhist remains is one of the reasons why I suppose there must have been more of the soil cultivated in former times than now. The population of monks who lived in these places must have outnumbered by many times the present inhabitants, and this implies a larger food supply. The construction of the monasteries,

with large and costly topes, all tell of a wealth which is no longer to be found there, and their decorations are evidences that art was practised. We know from the Chinese Pilgrim, Fah Hian, that there was a monastery at Hada "entirely covered with plates of gold."* The seven precious substances are constantly mentioned as the decorative materials of the structures. These were gold, silver, lapis lazuli, crystal, cornelian, coral and ruby. Precious and veined stones were also used. I found some remnants of gilding, which is confirmative so far of these accounts. From what I have myself seen I should say that most of the buildings were thickly coated with plaster, and decorated with bright colours—red and yellow being the predominating tints. Hiouen Thsang describes a tope at Nagarahara, the then capital of the district, as being 300 feet high, which was not only remarkable for its construction, but also for the sculptures upon it.† The same author, in describing the Amaravati Tope, makes a reference in connection with it to "all the magnificence of a Bactrian palace,"‡ showing the celebrity the region west of the Indus held in those days. You can imagine the appearance of this splendid valley when it was bordered all round with large monasteries and topes, decorated with such costly ornaments. Some of the topes were erected on spots where it was believed Buddha had visited, others were built in honour of relics. One in the town of Nagarahara contained a tooth of Buddha; one vihara had the staff of Buddha, and another had his robe. Perhaps the most celebrated of all was the one at Hada, where the skull-bone of Buddha was preserved and worshipped. It was the vihara containing this relic which has been already mentioned as having been covered with plates of gold. From Fah Hian's description it must have been a very wealthy establishment. The king and his nobles came every morning to worship the relic, and men sold flowers and incense at the gate to those entering to perform their devotions. A visit to this shrine was expensive. Hiouen Thsang paid 50 gold and 1000 silver coins, besides presenting silk banners and dresses for the monks.§

This place is 5 miles south of Jellalabad, and it retains its old Buddhist name; on the old maps it appears as Hidda, but in the new survey it will be given as Hada, which is nearer to the present pronunciation of the word by the natives. Hiouen Thsang describes it as being about four or five *li* in circumference, which is about a mile.‖ Judging from the remains as they exist to-day, this is an under-estimate of its size. There are a number of level-topped heights and ridges all covered with the remains of topes and viharas. The rock is conglomerate, and wherever it is scarped there are caves, forming what must have been a sort of underground town in addition to the one above. There are also subterranean channels for water cut in the rock. On all the heights round there are also remains in the shape of mounds, with caves in the rock below. The topes and rectangular mounds,—this last form indicating that they were viharas,—as well as the caves, show that this extensive place had been in itself wholly a town of Buddhist ascetics. About a mile south of Jellalabad there is

* Beal's Translation, p. 41.

† This was the Memorial Tope of Dipankara, Julien's Translation, vol. i. p. 97.

‡ Vie de Hiouen Thsang, Julien's Translation, p. 188.

§ Mémoires par Hiouen Thsang, vol. i. p. 78. Hiouen Thsang also states that "Ceux qui veulent voir l'os du sommet de la tête de *Jou-laï* (du Tathágata) payeront une pièce d'or; mais, pour prendre l'empreinte de l'os, ils en donneront cinq."—Julien's Translation, vol. i. p. 104. It is also recorded that it was equally necessary to pay in proportion to see the other relics. The sum mentioned in the text, as well as the presents of silk banners, &c., were for permission "d'adorer toutes ces reliques."

‖ Ibid, vol. i. p. 102.

a low ridge of heights extending as far at least as Sultanpoor a distance of seven or eight miles. The whole length of this is covered with remains and when the structures existed it must have had the appearance of a continuous town along all the extent of this space. The base of the Safed Koh towards Darunta where the Kabul river enters the valley is covered for about three or four miles with the remains of topes and the mounds of viharas. Opposite the junction of the Surkhab that is on the north bank of the Kabul river is a large cave known as the "Pheel Khana" or the "Elephant House" which gives its name to a large group of topes and caves. These extend on the heights as far east as the Barikot Tope, a distance of about two miles. On the Jellalabad side of the river are the remains of what I consider to be the site of the ancient capital known in the Buddhist time as Nagarahara where there are so many mounds of stones that the natives call it Wuzeerpoor or the "City of Stones." All along the projecting spurs of the hills on the north side of the river, as far as Mirza Kheyl and Girdi Kas—at this last there are remains on an island with a tope—are masses of ruins which I could distinguish from below, but as I only passed along there on one occasion, during an expedition against the Mohmunds, who occupied one of the eminences covered with ruins, my knowledge of these places is not so complete as it is of the other localities.

From this slight sketch of the extent of the Buddhist remains it is possible to form some notion of what the Jellalabad valley was when "the land glittered with the yellow robes" of the ascetics who dwelt there. At the present day nothing is left but mounds, and here and there a tope, which, although dilapidated and fast passing to the mound condition, still has some architectural features remaining. The heaps formed by the topes and the viharas* are tolerably distinct, the one being a rounded knoll and the other a hollow square. In many cases the centre of the square and the tope are on a straight line, showing a symmetry in the design. The Ahin Posh Tope was not arranged with its vihara in this manner; its square base is on the lines east, west, north and south, and my impression is that most of the Jellalabad topes are so placed, but there seems to be no rule as to the orientation of the approach. The Ahin Posh Tope had stairs on each of its four sides, a tope at Gunda Chismeh had its approach from the north, and that of the Ishpola Tope was the same: the Khaista Tope had its stair on the east, and in a small tope explored at Hada the stair was on the east. The group of small topes explored by Mr. Beglar at Ali Musjid are placed round a quadrangular building, and here the approaches are parallel to the side on which the topes are placed, showing I think that the Buddhist devotees were indifferent on the matter of the "eastern position." Under the projecting knoll on which the Khaista Tope stands there yet remains some of the Buddhist masonry of a tank about 300 feet square, so perhaps the approach to this tope was made with some reference to this particular feature. The principal approach to the inclosure of the Ahin Posh Tope was from the south: close at hand in this direction there is a slight hollow, which I suspect has once been a tank, and that it was this which determined the position of the gateway. Water is now brought close to this tope by means of a *karaiz*, a peculiar kind of underground aqueduct to be found all over Afghanistan, and by which water is brought great distances, but whether they are as old as the Buddhist period or not I have no knowledge. If this means of water supply did not then exist the monks at

* Vihara means "monastery"; being the name given to the buildings in which the monks lived. These places were also called "sangharamas." In Tibet at the present day a Buddhist monastery is called "gonpa."

Ahin Posh must have carried their water for about a mile at least, an arrangement which, from what I have seen at Ajunta and other sites of Buddhist monasticism, I should hesitate to accept.

Masson counted the topes in the Jellalabad valley, and gives the result as a definite number. Here I think he made a great mistake. He only included those on which he found fragments of their structure remaining, for he made an imaginary distinction between topes and tumuli. He was not acquainted with the Buddhist system, and that the ascetics had viharas or monasteries in which they lived, hence his being unable to separate the mounds formed by these buildings from the mounds of the topes. This is the reason that there are yet in the Jellalabad valley the remains of topes in the condition of mounds, which escaped the operations of his industrious activity. The Ahin Posh Tope which I explored might be described as a second class one as to size, and being apparently only a heap of earth he never touched it. On the site of the ancient Nagarahara is another one of the largest size, but it presents only the appearance of a mass of water-worn stones, and thus it escaped his attention. Had he excavated for the architecture he would not have attempted an enumeration of the topes. As I have just stated there are large topes which he did not include, and I believe there are monuments of this kind of every size, some being only a few feet in diameter; and such has been their quantity that, even when they were perfect above ground, it would have been a long piece of work to have determined the exact number, and now it is impossible. Every monastery in addition to its larger tope, had numerous small ones of various sizes. We subscribed a few rupees and had a small exploration carried on at Hada. This was close to one of the larger topes which had an extensive chasm in its side—most probably made by Masson; our operations did not extend over a great space, still we cleared out part of what had been a tope 29 feet in diameter, and it was surrounded by a series of smaller topes, about 4 or 5 feet in diameter.* Here we found some interesting fragments of sculpture; the quantity of plaster figures embedded in the earth, and close to the surface, was a matter of surprise to us all.

It may be as well to explain what a tope is; its genealogy may be thus given:—The primitive grave heap became a mound; stones were added, producing the cairn; the stones of the cairn, arranged in various ways, at last were built into a structure. From this result most probably grew the seven storeyed tower of the Euphrates valley, the pyramid of Egypt, and the Buddhist tope.† It will thus be seen that the tope belongs to an ancient and a most important branch of architectural development. In the north of China the heaped-up conical mound of earth is still the form of sepulchre followed; and that of the Emperor Yung-lo, the most important of the Ming tombs, north of Peking, of which I laid plans before the British Architects in December, 1873,‡ is a large mound, half a mile in circumference, partly built all round with a wall about 20 feet high, giving us an approach to the tope. I mention this as showing the possible transformation from the mound into a wholly-built structure, for we have as yet no reliable evidence as to what the tope was in the pre-Buddhist time in India. Whether

* In pl I., fig. 2, is a drawing of the base of one of these topes; two of them were cleared out, but the mound extended beyond where there is no doubt a third. The circular part of the monument does not remain; in this case stone had been largely used, but the whole is covered with plaster, on which are the remains of gilding and colour. The resemblance of this to an early mediæval tomb was striking when it was brought to light, and the drawing has suggested the same identity to all who have seen it at home.

† The Chinese pagoda, or storeyed tower, is again most probably a derivative from the tope.

‡ See the TRANSACTIONS, Sess. 1873-74, p. 33.

topes existed or not at the date of Nirvana we cannot tell. Buddhist tradition indicates that they were constructed at that epoch, but that is not a reliable basis to use alone as a foundation for theory. At the time of Asoka, which according to the accepted chronology is about three centuries after the death of Buddha, these monuments appear as being regularly constructed after an established style of architecture. At that date in India they were solid hemispherical domes, surmounted by a *tee*, over which were placed the symbolical umbrellas. The one at Sanchi, known as the Bhilsa Tope, is perhaps the best example to refer to. There is a small model of this monument in the South Kensington Museum, but it is to be regretted that it should be incomplete, as it wants the *tee* and the umbrellas. On the cast of the gates, exhibited in the same room, sculptured representations can be seen with all these details. The Manikyala Tope in the Punjab, already referred to, is another illustration of the hemispherical form.

On crossing the Indus a marked peculiarity appears, and that is the existence of a square base. In the Sanchi Tope there is a circular ledge 14 feet above the surface, with stairs leading up to it, showing that it related to some function at the ceremonies. At Manikyala this feature is very prominent; it is approached by four broad flights of steps from the four cardinal points. There are the remains of some smaller topes at this place, and two of them, known as Makam-ka-Pind and Sonala Pind, had each a square base. In the Yuzufzai country there are the remains of a tope with a round base at Jamal Garhi, and one with a square base at Takht-i-Bahi. After entering the Khyber the circular form disappears, and in every case, so far as I could judge by what I saw, the square base was the rule.

This square base seems to me to be a very important feature of the tope in the Indus valley and Afghanistan. There must have been some influence from which it originated, and if this could be followed up and the sources explained from which it sprung, a new light might be brought to bear on a subject about which we are much in the dark. Although not in the direction here indicated, suggestions have been developing themselves from this architectural feature. In connection with the Buddhist remains of Afghanistan, I have elsewhere pointed out that the chortens or topes, erected by the Lamas or Buddhist monks in Tibet, have a square base, which is a very prominent feature belonging to them. I pointed out what is highly probable, that they derived this form from Afghanistan, or as I expressed it—"from the right bank of the Indus and not from the left." There was added the suggestion that this might prove important as showing the probability of the Buddhist propaganda having first crossed into Afghanistan before it penetrated into Tibet. What is here hinted at as only a possibility, resulting from a peculiarity of architecture, Colonel Yule confirms as being perfectly historical, and I am indebted to that gentleman for some references on the subject. They are from Koeppen, who states that the first Buddhist king of Tibet was Srong-tsan-Gampo, who in 632 A.D. began the work of conversion and establishment. He sent his minister Thu-mi Sambhola with sixteen companions to India to bring back books and doctrines. It is not stated to what part of India they went, but Koeppen says that "Tibet received its Buddhism especially from regions in which this cultus,"—that of Avalokitésvara,—"flourished, such as Kashmir, Nepaul and Udayâna."* This Udayâna is a region on the right bank of the Indus between the Khyber and Cashmere, the present Swat and

* Vol. ii. p. 61.

Yuzufzai country. The same author also adds that Padma Sambhava, who is still the most famous apostle of Buddhism in Tibet, came from Udayâna in the eighth century. In stating these matters I am not forgetting that missions were sent out from India at the close of the third Synod, in 241 B.C., to the Himalayas, as well as to Gandhara and Cashmere. Whatever these missions may have done, they did not take designs for topes with them from Pataliputra, or, if they did, they were not followed in Tibet. I think that, as the Indus valley was a more constant route of communication than any other point in the south-east of the Himalayas, the connection between Udayâna and Tibet would be kept up better through this line, and here apostles, doctrines and architecture would naturally pass. The date of Srong-tsan-Gampo was the very time when Hiouen Thsang was in India, and talking of the magnificence of Bactrian architecture as far south as Amaravati. The most splendid tope in India at that time was at Peshawur. The Peshawur valley was full of viharas and topes, and the fame of these monuments would be enough in itself to carry the style of architecture into new regions where it was desired.

I have already mentioned the mound graves of Northern China, and an idea has suggested itself to me about them in relation to the square base of the topes. Under the conical heap of earth the Chinaman forms a square base of the same material. The square form is *Yang* and the round heap is *Yin*. These form a dual power of profound symbolic significance in Chinese ideas. Whether these ideas extended westward or not I cannot tell, though I think that sepulchral mounds exist all through Tartary; but if the square base of the Chinese grave could be traced towards the Hindoo Koosh, the origin we seek would be explained. The Turanian invaders, the Su and the Yuchi, who overthrew the Greek rule in Bactria, and under whom Buddhism flourished in Afghanistan, may have brought the form and constructed it with the prevailing style of architecture in the locality.

The word "tope" is understood to be derived from the Sanscrit of *stupa*, the *S* having been dropped out. The term was first used in reference to the Afghanistan monuments, from which region I think the word came. Masson uses "tappa" as an Afghan name in relation to both topes and mounds, and my working parties of natives seemed familiar with it. The Turkish word "tepé," which is applied to all mounds natural or artificial is so close upon this that it raises a question of identity. From as far west as the Troad to the east bank of the Euphrates this Turkish term may be found, and I suspect that "tappa" is only the same word, but I cannot pretend to determine the point. The Afghans have another title for all mounds or heaps; it is "goondi." As an example, the remains of a tope on the site of the ancient Nagarahara, already mentioned, they call "Nagara Goondi," which becomes in itself one of the identifications of the place.

As it became evident we should have a long detention at Jellalabad, I felt a strong desire to explore some of the mounds; and on making known my wish to the late Sir Louis Cavagnari, he at once placed a working party of Afghans, people belonging to the villages around, at my disposal, on condition that all sculpture or coins found should belong to the Indian Government. There was too much work going on in the camp, and on the roads of communication, to allow of an engineer officer being spared to take charge of the workmen, but a havildar of the Corps of Guides, named Kalah Khan, who had at one time served in the Sappers, acted as overseer. He could speak Puchtoo, the language of the country, and he

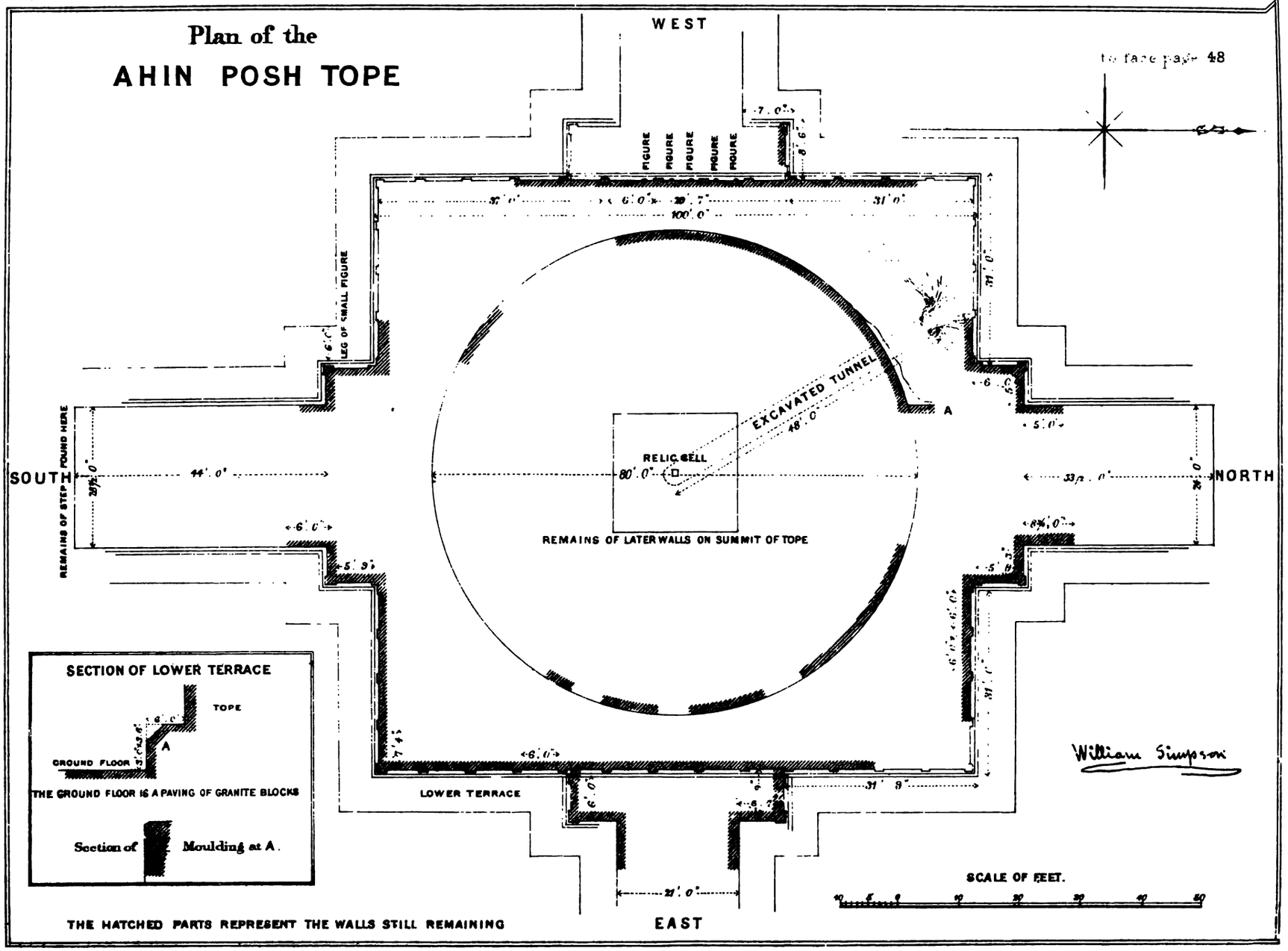
performed his duty in this case very well. About a mile from the camp, at the eastern end of a long line of heights to the south of Jellalabad, and which I have already described as being covered for many miles with remains, is an important group, with a prominent mound known as the Ahin Posh, or the Iron-clothed, Tope. Along with it are the rectangular ridges of the vihara, in which vestiges of Buddhist masonry can be seen in many places. This was the spot selected for exploring.

The first operations at the Ahin Posh Tope were made at my request by Lieut. The Honble. M. G. Talbot, R.E., who was at work making the South Hill Fort, a defensive work close by, from which he detached one or two of his sappers. The result was the discovery of fragments of one course of Buddhist masonry belonging to the circular part of the Tope.* On finding this, there was some doubt as to whether it was the upper portion we had come upon, from which the dome was sprung, or the first course resting on the platform of the square base. Previous to this there had been some uncertainty as to whether it really was the remains of a tope or not, for no masonry was visible: it was only a rounded mound of earth and stones. Here and there I could see that the boulders of which it was built were visible in layers, and this, although not conclusive, owing to my then limited experience, went a long way to satisfy my own mind. The few stones which were found left no doubt as to the character of the remains. When I began with the regular working party the first day's operations showed what I expected: that it was only the lowest course of the circular part that had been come upon, and consequently that all the upper portion of the monument had ceased to exist. This I confess was disappointing so far, but still I felt sure that some of the base would be found, and to obtain the details of this part of the monument was a sufficient motive for going on with the excavation.

I began a tunnel at once so as to penetrate to the centre of the Tope, and commenced it in a line from the north-west. This was to avoid coming upon the central part of the square base—should any of it chance to exist. There was enough of the circular course above from which to determine the diameter, and the measurements gave it so near to 80 feet that I put it at that figure, as being sufficiently close to represent its size. This makes 40 feet to the centre, and then there was a portion of the square base also to cut through. As I drove the tunnel ultimately a few feet beyond the centre, its full length may be put as close upon 48 feet.+ The tunnel had to be made high enough for a man to walk erect, and wide enough for the carrying out of the stones. One man only could work at the end, extracting the stones, which he did with a crowbar. These were all water-worn boulders, the largest being about a couple of feet in size; embedded in mud, the whole formed a compact mass so firm that no supports were necessary while making the tunnel. The boulders were to a certain extent built in layers. I had noticed in those topes formerly explored that the tunnel had been commenced rather high up, and a descent had to be made; seeing the trouble this would give the men in bringing out the debris, I determined on first finding the lowest course of boulders and making the original surface of the ground the floor of my tunnel. This turned out to be a fortunate plan, for it led me direct on the central cell, which had been constructed on this level.‡ There was

* See the plan on pl. II.; and also the sketch on pl. III. fig. 1, at A. + See pl. II.

‡ See pl. III., figs. 1 and 2, for level of cell. It was 2½ feet above upper moulding of square base, or 12 feet 2 inches above the ground floor of the Tope.


Plan of the
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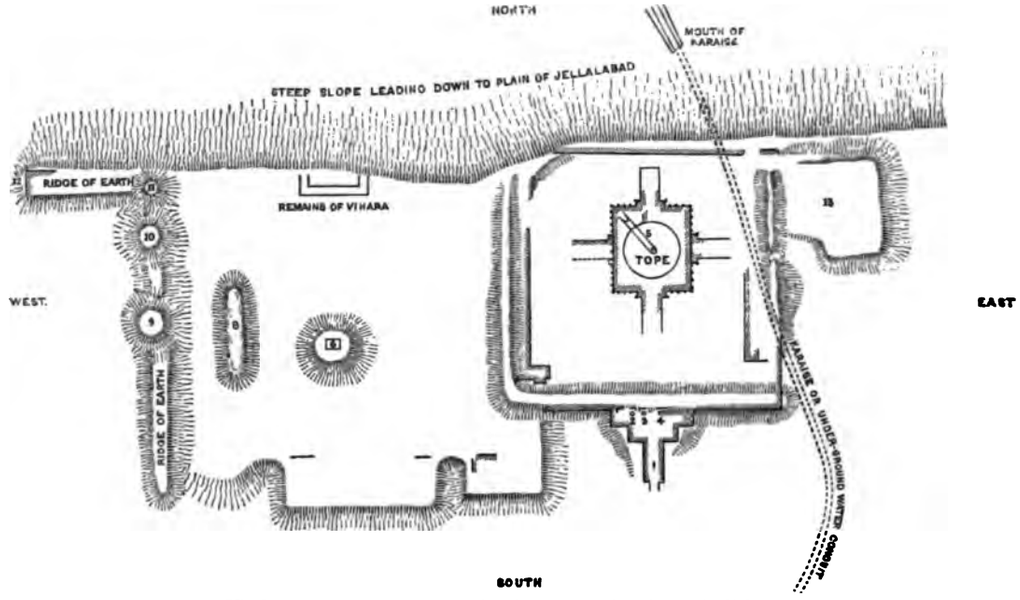
WEST
to face page 48
FIGURE
FIGURE
FIGURE
FIGURE
FIGURE
LEG OF SMALL FIGURE
EXCAVATED TUNNEL
RELIC CELL
REMAINS OF LATER WALLS ON SUMMIT OF TOPE
SOUTH
NORTH
REMAINS OF STEP FOUND HERE
LOWER TERRACE
EAST
SECTION OF LOWER TERRACE
TOPE
GROUND FLOOR
THE GROUND FLOOR IS A PAVING OF GRANITE BLOCKS
Section of Moulding at A.
SCALE OF FEET.
THE HATCHED PARTS REPRESENT THE WALLS STILL REMAINING
William Simpson

no variety in the manner of building, and when at last it was reported that some slates were visible I knew it was the cell which had been come upon. Being anxious to understand the arrangement and construction of this part of the monument I remained in the tunnel while the stones were removed on each side and beyond the slates; and it was only after the space was cleared out, and the part containing the cell could be seen all round, that I began to open it. It formed an oblong heap, quite rude externally, about 4 feet long and about 3 feet wide. On the top was a large slate extending to nearly these dimensions, and about 1 inch thick. On being raised it was found embedded in mud, with another slate slightly larger in size under it. On raising this last the cell was disclosed; it was a cube of 16 inches, formed of small slates about 6 inches long and half an inch thick, and their edges, which formed the surface of the cell, were smoothly trimmed, but not polished. They were placed very regularly, so that they formed a very well made receptacle. The bottom was formed of another large slate. I had expected to have found a vase or jar of some kind containing the relics, these having been repeatedly found in topes; but there was no other inclosure than the cell which I have just described. In this instance there were about two handfulls of dark brown dust, which I presume was part of the ashes of the person in whose honour the monument had been erected. On the ashes lay a golden reliquary set with stones, and this was about 4 inches long and an inch wide; it was octagonal in form, and had two bulbous projections, with holes for the cord by which it was worn round the neck.* One end came off, and within was a small hard substance, which may have been a relic; there were also two gold coins in it—that being all it contained. Among the ashes I found eighteen gold coins, making a total of twenty. They were all about the same size, slightly less than an English sovereign, and weighed about two drachms each. Seventeen of them belonged to Indo-Scythian monarchs, extending over three reigns, that of Kadphises, Kanerki, and Hverki. The other three were Roman coins belonging to Domitian, Trajan and the Empress of Hadrian. The reign of the first of these Indo-Scythian monarchs is generally given as during the century before Christ. The Roman coins come down to the first quarter of the second century of our era, and are of value as giving the limit of possible antiquity to the monument.

The making of this tunnel took nearly a month, and while it was going on the larger number of the working party were clearing out the base of the Tope. I had commenced the excavation on the west side, and found that it originally had 14 pilasters. At the corners none of the base existed, except at the south-east corner, but towards the middle it still remained about 15 feet high, with portions of eight pilasters.† I was able to make a section of the base mouldings, as well as of the base of the pilasters. I regret to say that in no instance were the capitals left, the pilasters being all destroyed to a point below that member. The Tope had been originally constructed with stairs on the south and north, but at some later period similar stairs had been added on the east and west. These were identical in plan with the first stairs, and when I came upon the remains of the stair on the west it was the cause of great perplexity to my mind. I only found the northern portion of its wall, built up against the built square base of the Tope; the pilasters had been covered up without destroying them, and as there were five sitting Buddhist figures found on the upper part of the base mouldings, the natural conclusion at the moment seemed to be, that it was an inclosure forming a shrine;

* See pl. III., fig. 4. † See pl. III., fig. 2.

the absence of the inner face of the wall being what I could not understand. Further explorations made it all clear. As was their manner, they built the outer facing of the stairs and filled up the whole space with boulders and mud, covering up the pilasters and figures within. The masonry was different from that of the rest of the Tope, and the junction of the new work was irregular,—a small space being left between the pilasters at the junction, which does not exist at the north and south stairs. I cleared out almost all round the square base; it was exactly 100 feet on each side. The corners had suffered most from dilapidation, and the south-east corner was in the best condition; at this point a small portion



SKETCH-PLAN OF AHIN POSH TOPE AND MOUNDS OF VIHARA.

5, Tunnel into centre of Tope; 1, remains of principal gateway and approach from south; 2, 3, 4, remains of colossal figures in plaster; 6, mound of stones and mud in centre of Vihara; 8, 9, 10, 11, 12, mounds and ridges of earth, which seemed to be remains of a village built on old walls of monastery; 13, an inclosure formed of mounds. Round the Tope are remains of the Buddhist walls, partly explored. The *karaise*, or water conduit, on the east, is at least some 20 or 30 feet below the surface of the court in which the Tope stands.

of the lower part of the base existed, it having entirely disappeared from the other corners. The Tope was faced with the usual Buddhist masonry and thickly coated with plaster. I feel sure that it has been decorated with colour, but cannot affirm that any of it existed, except on one of the figures found on the west side, where there are distinct remains of a bright yellow colour, which may be taken as evidence that this was the colour of the Buddhist robes in that part of the world. On the western side of the south stair were the remains in plaster of the legs of a small standing figure; beyond this, and the other five figures on the west, I was no other evidence of similar remains on what is left of the Tope.*

My reason for beginning the excavations on the west side was because I thought that

* See pl. III., fig. 3, which gives one of these five figures. It is about 3 feet high, and the nimbus is in form of a lotus leaf.

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THE AHIN POSH TOPE.

FIG. 3.

BUDDHIST FIGURE IN PLASTER ON WESTERN BASE.

FIG. 4.

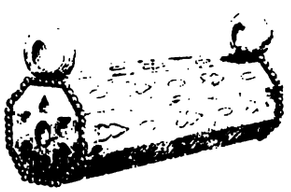
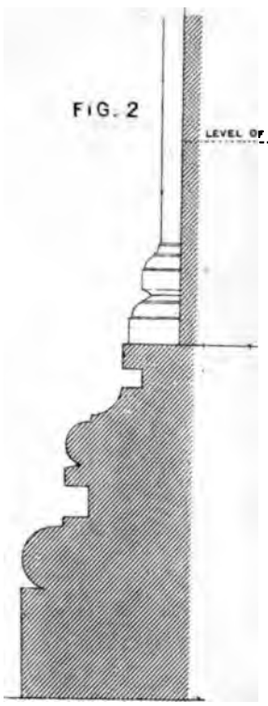
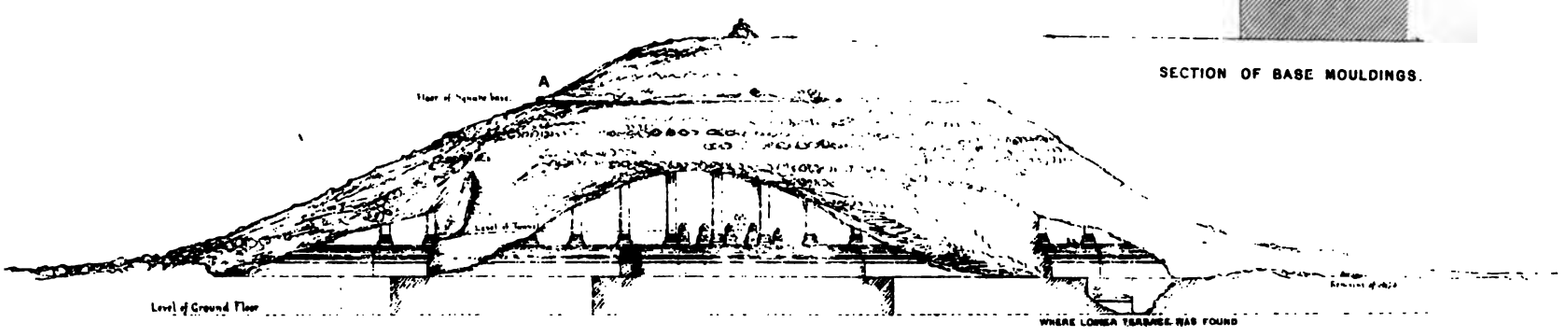


FIG. 2



SECTION OF BASE MOULDINGS.

FIG. 1.



THE AHIN POSH TOPE NEAR JELLALABAD.

William Simpson

Photo Lith^d by C. F. Kell Castle St Holborn, E.C

the principal approach would be there, owing to the remains of the vihara being in that direction. There is a rectangular ridge round the Tope, which had formed an inclosed court, and to the west of this is a larger rectangle, full of mounds, which no doubt was the monastery.* Here I regret to say time did not permit of excavations. I managed to clear out some portions of the rectangular ridges round the Tope, and came on the remains of the entrance on the south side, suggesting that the principal gate was for the public, and not exclusively for the monks who dwelt on the spot. The approach is on a line with the axis of the Tope, and it must, from the plan, have been a place of some architectural pretensions; this conclusion was confirmed by the discovery of portions of colossal figures. The best preserved of these were two human feet *in situ*, each of them being 23 inches in length; they are modelled very beautifully in mud, and covered with fine chunam. I regret exceedingly that, owing to the material, they could not be preserved. The position of the feet shows that the figure stood facing the worshippers as they advanced towards the shrine. The probability is that this court round the Tope contained smaller shrines with figures in them, an arrangement which we see in the plans of Tahkt-i-Bahi and Jamal Garhi.

There are the remains of a square tower built at a late date on the present summit of the Tope,† and modern walls of rude masonry, not Buddhist, have been constructed all round the old line of the court inclosing the Tope. On the northern side this more modern wall is built directly on the Buddhist one, but on the south it is neither on the old wall nor is it quite parallel to it; from this the conclusion is probable that the whole place was in ruins when the later erections were made. On the north there is the steep bank down to the alluvial plain of Jellalabad, where the débris of the first structure on that side has fallen, thus leaving the wall visible to use as a foundation; on the south a ridge of rubbish was the result of time, and the later builder began his wall on that, and hence his deviation from the old line. These later walls were no doubt the work of some Afghan chief, who had made the place into a stronghold, and as very little of it remains it may have been excavated centuries ago; the supposition is that if he wore some particular kind of armour, this perhaps may have given the name of "Ahin Posh," or "Ironclad," to the spot.

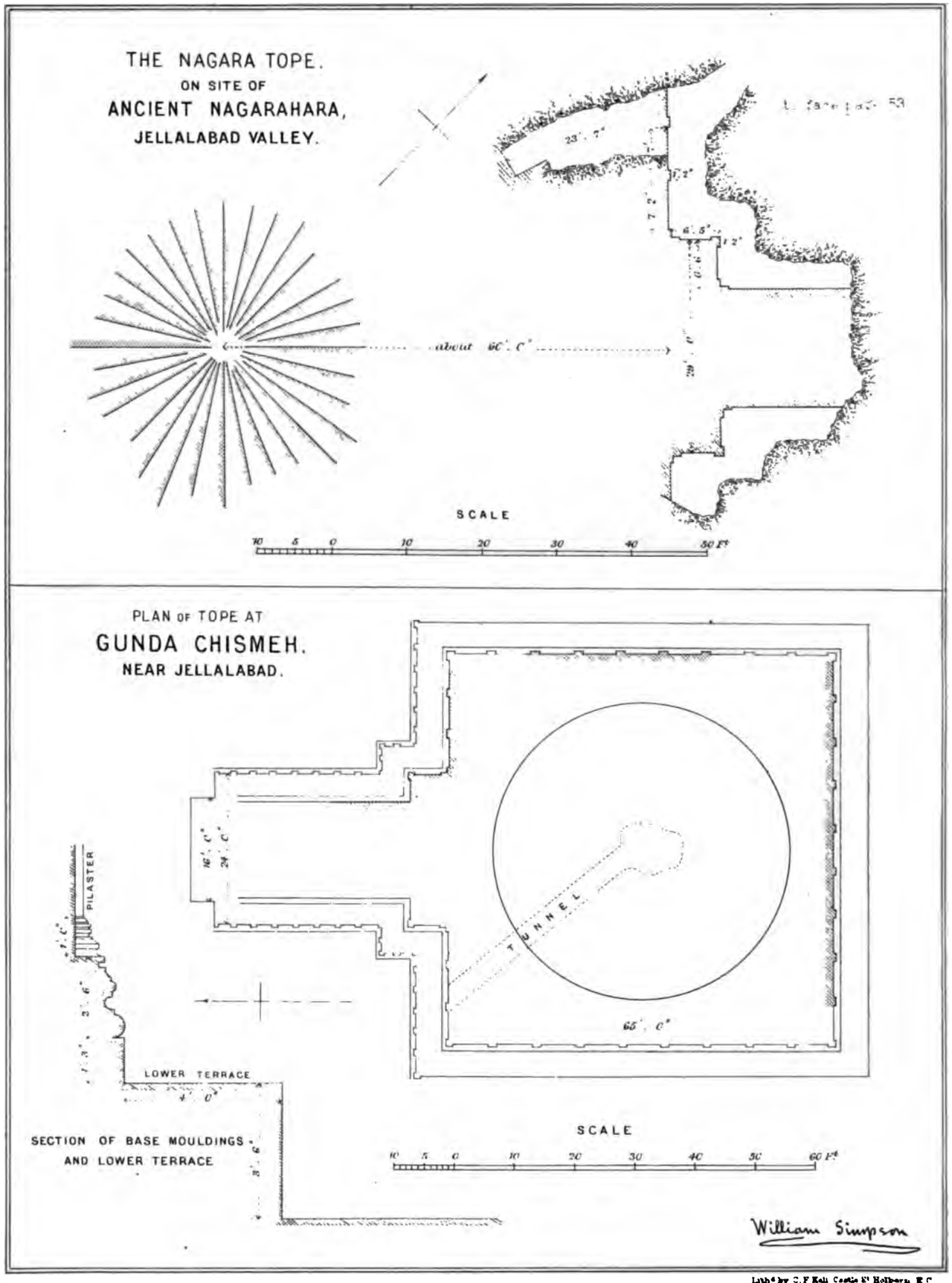
There is a very tempting mound at a village called Gunda Chismeh, which is on the same ridge of heights, about a mile to the west of the Ahin Posh, and to this I removed the working party. Although unsuccesful so far as the finding of coins or relics is concerned, yet it was fortunate that I explored this tope, for it revealed to me a feature which might have been otherwise overlooked. At this monument there exists a terrace, 4 feet wide, and 3½ feet above the ground floor, faced with small pilasters, which goes round the whole of the square base, following exactly the outline of its plan.‡ On finding this at Gunda Chismeh, I sent back some of the men to Ahin Posh to see if such a terrace existed there. Although they excavated for a couple of days, no trace of it could be found, and the search was given up. It turns out that the terrace does exist. After our advance to Gundamuck, the Sappers followed us, and on their arrival Lieut. Bartram, R.E., brought me a section of it.§ It chanced that Dr. Amesbury, who was attached to the Sappers, made some excavations at Ahin Posh after I left, and he came upon the terrace by accident. On my second visit to the

* See woodcut, p. 50. † See pl. II., on plan. ‡ See plan of Gunda Chismeh Tope on pl. IV.
§ See "Section of Lower Terrace," pl. II.

Ishpola Tope, I naturally looked for this feature, and there is a space round the square base of it, quite wide enough for such a terrace. In the smaller topes explored by Mr. Beglar at Ali Musjid, the repetition of this terrace is visible, although too small to have served for any use,—still this is evidence that it formed a part in all the designs of these structures in that part of the world.

Such being the case, the question naturally arises, for what purpose was this terrace used? I have not chanced to come across any effort to explain the purpose of the circular ledge with its stairs, which belongs to all the Sanchi group of topes, and which may be considered as the counterpart of the floor of the square base of the Afghanistan examples, so that the question here put, involves the object of this part of the Sanchi examples as well, and so far as I know it is probably quite a new one. The Afghanistan topes seem to have had no railing round them, such as we find at Sanchi, Bharhut and Amaravati, and it may be presumed that the lower terrace represents that feature, and its understood purpose was for the worshippers to circumambulate the shrine while doing their *poojah*. This still leaves the large space of the square base unaccounted for, and its importance, from the large stairs leading up to it, shows that it was connected in some way with the ceremonies. If the size of these topes did not tell us, we might infer from the arrangement of the chaitya temples of the rock-cut caves, that they were the high altars, or cathedral churches, of the Buddhist system; consequently, there would be some form of elaborate service performed at them. My opinion is that the monks sat on the square base chanting from the books of ritual, accompanied with musical instruments of various kinds; Fah Hian mentions the use of great drums, conches and cymbals at Hada.* It is also quite possible that the worshippers may have circumambulated the place first on the lower terrace, and then finished their *poojah* by doing the same on the platform above. Or they may have only ascended the stairs on each round, and worshipped the large figures facing them. As the ledge of the Sanchi Tope is only 5½ feet wide, if the monks occupied it, there would be no space left for worshippers to walk round, hence I suspect that going up the stair at each performance of the *pradakshina*, as it was called, and returning again to the lower terrace would be the most likely rule. It seems to me that this would be in perfect keeping with what I have myself seen in the Buddhist monasteries of Tibet, where I have often sat sketching while the monks were performing their long and elaborate ceremonies. Judging from what I saw there, my notion is that in the chaitya temples of India the nave was reserved for the monks, while the public passed up and down the aisles, to worship at the chaitya or tope, at the end. The Buddhist ritual took a considerable time to perform, and being complicated, the music coming in as an accompaniment at particular parts of the service, a reserved place had to be found for the officiating monks, where they would not be disturbed by the crowd. In the square base of the Afghanistan topes, as well as the ledge of the Central India monuments, we find the desired arrangement. If this is the correct view of the matter, the narrow ledge of the Sanchi Tope must have caused the monks to sit in a row all round, like the small figures on the lower moulding of the Ishpola Tope,—that arrangement of statues being most probably derived from the customary manner the monks had of placing themselves.

* Beal's Translation, p. 42; and in Hiouen Thsang, Julien's Translation, vol. i. p. 112, allusion is made to "musique extraordinaire," and to the "rares parfums" at a tope.



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Colonel Jenkins, of the Corps of Guides, made an attempt to open the Nagara Goondi Tope, which has been already mentioned, but I regret to say that the advance to Gundamuck stopped the operations. Very little was done, but that little brought to light some very important points in relation to the topes of the Jellalabad valley. While Colonel Jenkins' party were at work on a tunnel to the centre, I asked for a small party to explore the outside in order to obtain whatever details might be remaining of the architecture; this, Major Cavagnari at once arranged for me. The Ahin Posh Tope has been described as a heap of earth and stones; the Nagara Goondi seemed on the contrary to be a cairn of rounded boulders, for the bed of the Kabul river, close at hand, had afforded an easy supply of material. It was a large mound, but on discovering the remains of the square base I was somewhat surprised from the measurements to find that it had been a larger tope than the Ahin Posh. The Ummer Kheyl Tope, of the Darunta group, is perhaps the largest one of which there are remains in the Jellalabad valley. A rough measurement gave 300 feet circumference to the circular part of it, making it 20 feet more in diameter than Ahin Posh. The measurements, obtained from the small part explored, indicated that if the Nagara Goondi is not exactly as large as the Ummer Kheyl, it is very close upon it. The measurements made with a tape line over the mound of stones cannot pretend to accuracy, but I think the square base is 120 feet, and the circular part is close on 100 feet in diameter. I managed only to clear out a portion of one side, and found the plan of the stairs similar to that at Ahin Posh. It has the same pilasters on it, and the mouldings are very much the same. One difference was noticeable: the plastered surface seemed more decayed. I do not mean that it was broken off, but it was more mouldy or weather worn, and suggested a greater age, than the plaster at Ahin Posh, at which place the plaster is in very good condition for a monument which has existed so many centuries. The great interest of the excavations at the Nagara Goondi Tope results from some constructive peculiarities. It is faced with the usual Buddhist masonry, but on the top of the heap are a number of lines radiating from the centre of the Tope; none of them seem to extend exactly to the centre, and they disappear again among the boulders towards the circumference. They are formed of Buddhist masonry, with a face formed only on one side. This is all that could be made out externally. Colonel Jenkins began his tunnel under my advice, on the same level as the one at Ahin Posh, which is just over the base mouldings, and before reaching 20 feet he came upon a wall on the left, which seemed to be on a line direct to the centre. This I had no doubt was the continuation of one of the lines visible on the summit above, and the conclusion is, that these spines or diaphragms were constructed all through the Tope, to give stability to the mass; it is an evidence of great care on the part of the builders. A few feet further on, another wall was found right across the line of the tunnel.* Only a few feet of this wall were brought to view, and it is scarcely possible to say whether it is circular or not, but I think it is so; still, there need be little hesitation in coming to the conclusion that it must be the wall of the circular portion, which had been begun on the level of and carried up inside the square base as a means of strength to the structure above. Neither in the tunnels of the Ahin Posh, nor at Gunda Chismeh, was such a wall met with. If some starting point for the dates of these remains can be found, this peculiarity of construction will no doubt be valuable for working out the results. I had visited the Pheel Khana and the Barabat Topes,

* See plan of the Nagara Tope on pl. IV.

and in looking into the large chasms made by Masson, I noticed walls; but I hastily assumed they were made by him to support his excavation, and unfortunately did not minutely inspect them. I have no doubt now but they were similar walls to those I have just described. Masson gives plans of inner construction, but so far as I have been able to study them they seem a puzzle.

I have made a sketch restoration of the Ahin Posh Tope, but it should be stated that the effort has been rather to combine the features to be found on more than one tope still remaining in the Jellalabad valley, than to represent the particular one named. I have used the plan of the Ahin Posh, and placed upon it the highest architectural development which the style seems to me to have reached in that region. On all the topes of the Jellalabad valley in which capitals are remaining, I found them to be Corinthian, and they are so introduced into the restoration. Plans of the Ahin Posh Tope, as well as sections of the mouldings, were made by Lieut. Mayne, R.E., and sent to General Cunningham. In the Proceedings of the Asiatic Society of Bengal for last year, a restoration of one of the pilasters appears, which has been made by the General. He makes it Ionic. All the fragments of sculpture, and other remains found during the explorations, were preserved and sent to General Cunningham; and among them he found a fragment of an Ionic scroll in plaster, upon which he has based his restoration. Here the General has been led into a mistake for which he is not at all responsible. I have a sketch of the fragment, and it was found in our explorations at Hada, so it had no connection with Ahin Posh. Some of the objects found at Hada must have been sent with the others, and hence the cause of his wrong conclusions. The fragment is valuable as showing that Ionic was not unknown, but I can say that none of the topes, large or small, from Ali Musjid to the Siah Koh Range, as far as I saw, have Ionic upon them. This will explain my use of the Corinthian. General Cunningham also adds a hemispherical dome to the elevation of the ruins. In this he makes it something like the Manikyala Tope and the Indian topes; but it should be stated that this does not give the height of the cylindrical part of the building, which is an important feature of the Afghanistan topes. In none of the topes, except that of Ishpola, do any of the domes exist. Masson gives a number of domes with a pointed arch, but I do not know what authority he had for this, and I doubt its accuracy. The Ishpola Tope is my authority for the round dome. The Barabat and the Khaista Topes give me sufficient examples for the space between the dome and the upper cornice. The Jani and Barabat Topes have only one belt of pilasters, but in the Pheel Khana Khaista and Bimeran Topes, and in those about Kotpoor, the double belt exists, and they illustrate the higher architectural development. In the upper belt in these instances there is in all of them an arch between each pilaster, which will be found in the restoration. So far as my experience goes there was no arch in the lower belt. Above the upper cornice, which is in every case Greek in its details, is a heavier cornice, with a greater projection; this rests on stone brackets of an ogee form. Between the two belts is a space, but on none of the topes did I find any remains of its details. There is an ornament, a continuous wreath or roll of flowers, which has often been taken for a serpent, for it is represented as undulating like one; it is on the Amaravati rail, and is found on Buddhist remains as far north as Jellalabad, for I have it on a fragment of stone from Hada, in which little figures support the coils. In a small sculpture of a tope in the Lahore Museum, from the Yuzufzai district,

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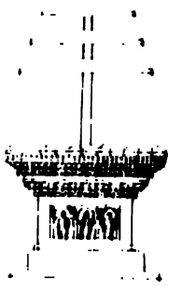
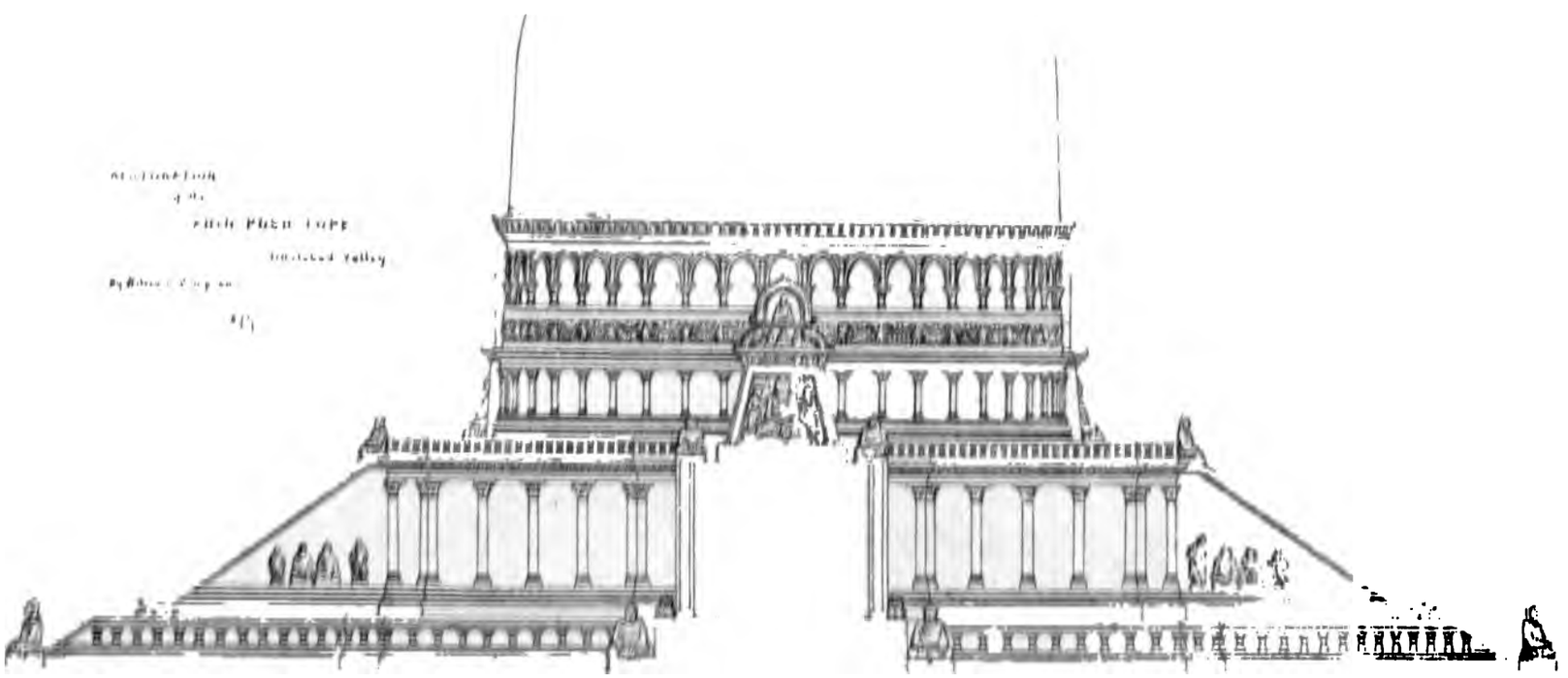




it appears prominently among the ornamentation, and being a thus favourite feature I have introduced it into this space. At the Ahin Posh the lower course of masonry of the cylindrical portion, which, as I have mentioned, is all that remains, stops short on the north side, and has a projection about 2 feet in length towards the stairs.* This I take to have been the lower part of a projecting base on which rested a large figure. I also saw what I suppose has been a similar projection at the Ummer Kheyl Tope. It is equally reasonable to assume that there would be figures facing each of the four stairs. There were figures within each of the four gateways at the Sanchi Tope. These may have been the four Buddhas or the Devas of the four gates or quarters, described by General Cunningham as having existed at the Bharhut Tope. There is no authority from the Afghanistan remains as to how these figures were placed, so I have fallen back on the Yuzufzai district, the nearest to the locality I am dealing with; and on a sculptured tope from that place, in the Lahore Museum, there is a figure represented sitting in such an arrangement as I have given. The platform of the square base requires a rail, and I have introduced the well-known "Buddhist railing" for this purpose. That it existed in the Jellalabad valley, I am certain, from finding fragments of it at Hada. From the small tope explored at Hada, as well as the topes at Ali Musjid, I have come to the conclusion that the stairs had no railing; there was only a low ledge bevelled at the corners, and that part is so restored. The same small tope at Hada shows that there have been figures at the foot of these ledges, and at Ali Musjid there are lions at the sides of the stairs; these are also introduced. More figures might have been put in, and authority given for them, but there are sufficient to convey an idea of the character of the monument. The lower terrace may have had a railing, but it is not here represented. The sides below this terrace have small pilasters, similar to what was found at Gunda Chismeh. The *tee* on the summit is taken from small models in the Lahore Museum from the Yuzufzai remains; on the authority of a small model of a tope, found by Masson in Afghanistan, a greater number of umbrellas might have been represented as surmounting the whole; but the triple umbrella was the original number in India, and it is here retained.†

The pilaster in the upper belt of these topes requires a little further explanation. It is formed in reality of two parts. The lowest is a very short pilaster, with Corinthian capitals, and over this is a long projecting stone bracket. Above this again is a half-round attached pillar, with the bell-shaped Persepolitan capital, surmounted by a block, which takes the place here of the two horses peculiar to that style. In the small topes at Ali Musjid, Braminic bulls are represented instead of horses; this in itself should leave no doubt that the bell-shaped capital came from the Euphrates valley. The arch form, which figures on this belt, springs from the end of the stone bracket over the Corinthian capital, and is pointed only on its outer moulding. It is found in the Yuzufzai remains, where it appears in many forms, for the most part in a decorative character, as the Greek pediment became. Its identity with the arch of wooden origin, so peculiar to the Buddhist rock-cut temples, need not be doubted.‡ The arch of wooden origin is in this case built of slate, on the arch principal; the slates are partly cut to give the outer moulding, but the exact form was worked out in the plaster. All the mouldings are formed by layers of slate placed with their edges to give the turn of the curves, the whole being afterwards finished with plaster. Where the plaster

* See A in the plan on pl. II. † See pl. V for this restoration. ‡ See pl. VI., figs. 1 and 2.

was gone I found it almost impossible to sketch the outline of these mouldings, the horizontal lines of the slate made it so confusing. I also give a sketch of a Corinthian capital without its details, it is interesting as showing how they went about their work. The abacus is formed by a slate rudely cut, and pieces of the same material are inserted on which to detail the acanthus leaves with the plaster. These simple fragments are so artistically arranged that one can scarcely fail to see, even in this state, the "core" for a Corinthian capital.*

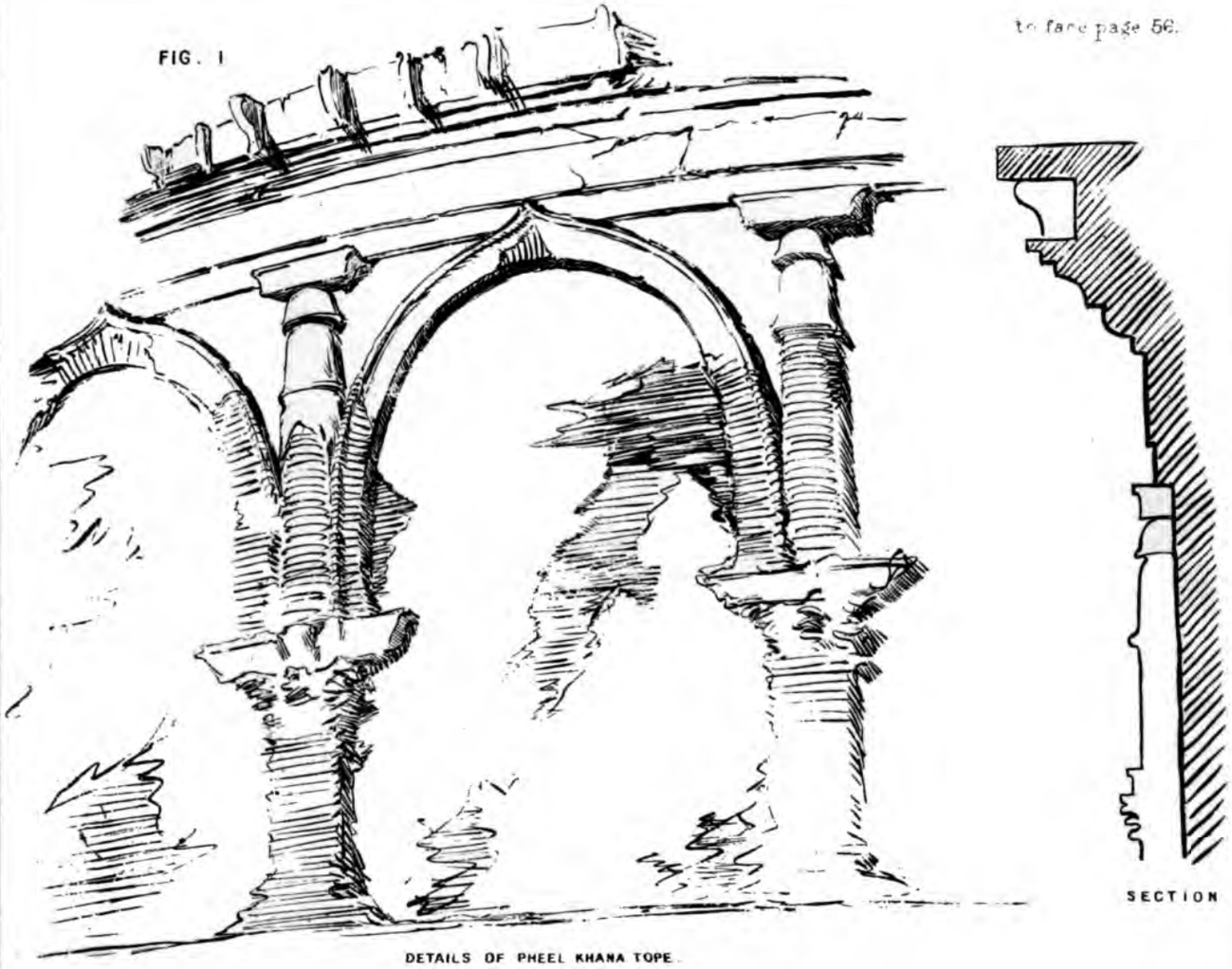
There is what I may call a strange form which appears in the Yuzufzai sculptures, and also in the Afghanistan remains.† It is often placed along with the arch just described, and seems to be interchangeable with it. I have a theory about this form, but I at the same time confess to having very little evidence to give in support of the idea. This may be described as two sloping jambs with a lintel over them, and I take it to have been originally a door. So little of the walls of the monasteries is left, that the form of such openings as doors or windows is rather uncertain. At Lundi Khana, in one of the ruins on the south side of the Pass, I found a window, the lintel of which was gone, but the sides sloped inwards to the tope; among the walls of the vihara at Ishpola, I found part of a constructed opening—I am not quite sure what it was—the sides of which also sloped inwards. I think that in Tibet sloping jambs of doors are found, and the connection between Afghanistan and that country may justify the supposition that it is a continuation of the same form. My notion is, that this is the pre-Buddhist construction of doors in the region of the Indus valley, Afghanistan, and of the Himalayas, towards the Hindoo Koosh; it was of course a wooden form, and implies a flat roof. I take it to have been, in the locality just named, the counterpart of the round Buddhist arch, of what I may call India proper, and that the round form originally belonged only to the south of the Punjab. I give this suggestion as it has formed itself in my own mind; the materials on which it is founded are of the scantiest, but it may lead others to investigate, and if it could be established, it would throw considerable light towards explaining the first sources of the architecture of Hindostan.

At Hada I found in one of the topes explored by Masson, that one tope had been built so as to inclose another; this process we know took place in Ceylon. Masson's excavation had in the lower part cleared out the first tope, and its form, like a matrix, was left. I made sketches of this, but they all seem too perfect as a representation of the rude mould remaining. The small tope had been about 9 feet in diameter, and so far as I could judge it seems to have been of a different shape from the later topes.‡ The Hada topes are generally rude shapeless masses now, but they are markedly different, I think, from the others in the Jellalabad valley. This particular tope, in which was found the matrix of the other, has some of its external masonry standing, and it is not the usual Buddhist kind. It is built of small squared fragments of a coarse calcareous stone. Masson calls the spot "Gundi Kabul," and the topes here, as well as others at Hada, are, judging by small fragments left, of the same style of building. Being all very much ruined, and no architecture left, no comparison can be made from their styles of architecture. Still the absence of Buddhist masonry is in itself a very marked difference. The ruined condition of the remains contrasts with the fragments of architecture still visible at the Darunta group, and suggests the possibility of a greater antiquity belonging to Hada. The Ahin Posh cannot be older than the second century

* See pl. I., fig. 1. † See pl. VI., fig. 3. ‡ See pl. VII., fig. 1.

to face page 56.

FIG. 1



SECTION

DETAILS OF PHEEL KHANA TOPE.

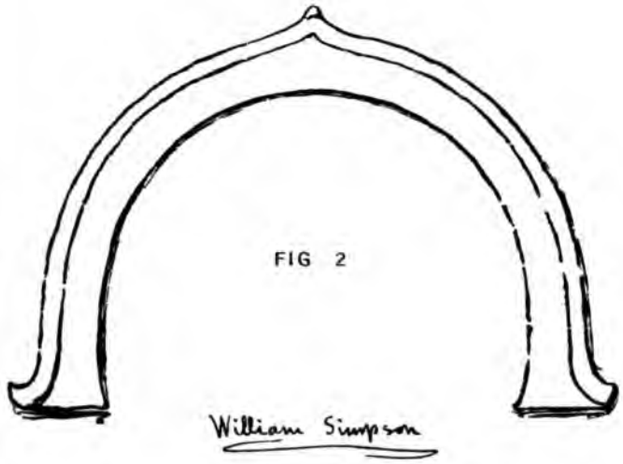


FIG 2

William Simpson

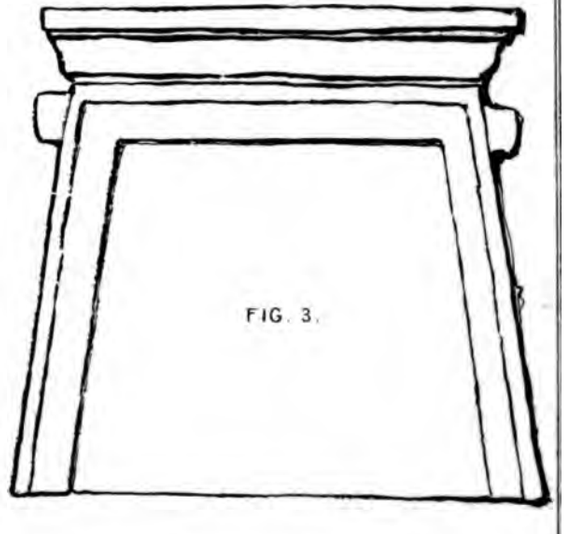


FIG. 3.

Photo-Litho by C.T

of our era, but I am inclined to think it may have been two or three centuries later. The Nagara Goondi is probably older, my impression is that it is much older. A copper coin of Apollodorus, with the tripod of Delphi on it, was found in the piece of the tunnel that was made. This king's date is given as 110 B.C. It would be an important point if it could be established that a Buddhist monument existed as early as this in the Jellalabad valley, and I regret very much that the exploration of this tope was not finished. As it stood on the site of the ancient Nagarahara, it may have been the Stupa of the Tooth mentioned by Hiouen Thsang as being in the interior of the town, and which he describes, even at the time of his visit, as being "antique," and that it was remarkable for "its elevation, its size, and its magnificence."*

The caves of Afghanistan are intimately associated with the Buddhist remains; they are generally found together. As already explained the monasteries stood on elevated ground, and the caves are in the scarped rock beneath. The quantity of these caves is as much a matter of surprise as the quantity of heaps and mounds of what have formerly been structural erections. They are simple recesses excavated in the rock. They vary in size, but if I say 20 feet long, 12 feet high and 10 feet wide, it will convey a rough notion of their average size and proportions.† In some cases two of these are connected by a passage behind, and one cave at Hada has still larger ramifications. One of the most important groups of caves is at Darunta; the front of the perpendicular scarp overhangs the Kabul River, and a long tunnel is cut in the rock behind the caves as a means of communication. The people there call it "the Bazaar." At this place, on the face of the same cliff, is a large niche, perhaps 30 feet high, in which we may presume a colossal figure of Buddha sat looking over the stream and the valley beyond. None of it now remains. Most of the caves at Ajunta, in Western India, are of the vihara kind; they are monasteries, formed of a central hall, with numerous cells all round. In Afghanistan, as far as my observation went, I only found one cave arranged on the vihara plan of Western India; this is one of the Pheel Khana group.‡ All the others are on the separate cell principle. A similar rule prevailed in Ceylon, where vihara caves are not found. According to Hardy, the space allowed in that island for the cell of a Buddhist ascetic was 12 spans long by 7 spans wide. The Afghanistan monks were not quite so limited for space as this statement would imply. The earliest Buddhist caves in India are separate cells, and my guess is that this type must have been carried beyond the Indus by the first propaganda, at an early period before the rock-cut viharas began. The resemblance of the Afghanistan caves to those near Buddha Gaya is not confined to the similarity of type, or to the size alone. The arched roof found in nearly all the Afghanistan caves is a marked point of identity. Where the arch terminates, the wall recedes an inch or two, leaving a drop-ledge—this being another peculiarity of the early Buddhist caves of India. Most of the caves in Afghanistan are in a very decayed condition, but in one or two I came upon, rather better preserved than the others, the sides sloped

* "Qu'il était remarquable par son élévation, sa largeur et sa magnificence," Julien's Translation, vol. i. p. 97.

† See pl. VII., figs. 2 and 3, which gives a plan and section of a cave.

‡ See pl. VII., fig. 4. This sketch plan shows also the Pheel Khana Cave, the two being close together. This last gives now the name to the whole group of caves and topes at this place. The Pheel Khana Cave is unlike all the others in plan and appearance. The entrance is very high, and elephants may have been kept in it, and hence the name, which means "Elephant House." The Rev. S. Beal has suggested that the tope, of which the remains exist on the rocks above, is the "Pilusara," or "White Elephant Tope," mentioned by Hiouen Thsang.

inward towards the top. From some former remarks on sloping door jambs, this may have been done by the people on the right of the Indus after their own models; still, it is a feature to be found in most of the early rock-cut caves south of the Indus. The Lomas Rishi and the Bhaja Caves, may be cited as examples. In most of these Afghanistan caves there is a small recess, which I take, from its size,* to have been for the bed of the ascetic, and this leads to the suggestion that the cave itself was fitted up as a shrine to which devotees would come. The caves were all thickly plastered, and I have no doubt painted, for some fragments were found remaining in a small cave at Hada, and frescoes we know existed in 1842, at Bamian.† There is a nomadic race, called "Koochis," who live with their flocks on the higher lands in the north during summer; they come down to the Jellalabad valley in winter, and use these caves as their dwellings. The result has been the utter ruin of the interiors; every part has been covered by a thick black deposit from the smoke, so that all decorations or inscriptions are lost. At Hada there are a few small caves of a distinct character; these are square, with a dome in the centre of the roof, which is otherwise flat. One of these caves is scarcely over 6 feet square; 11½ feet and 13 feet is the size of two others.‡ It was in the smallest of these caves,—its smallness being such that the Koochis could not use it, and it thus escaped the effects of smoke—that a fragment of painting was found with the colours as perfect as if only recently put on.§ On the small dome of this, as well as on that of others, the remains of painting were visible, nearly all of them Buddhist heads with the circular nimbus. An excavation in one of these square caves brought to light a portion of a base under the dome, with figures in plaster on it. This may have been for a Buddhist figure, or a small tope. If the last be the case, it forms a curious contrast to the splendid chaitya caves of Western India.

In conclusion I may be allowed to express a hope that further explorations will be made in Afghanistan. The existence of a style of art, coming from the valley of the Euphrates, and probably dating from the time of Darius, is now made clear. That the Greek architecture of Bactria came south, and crossed the Indus, is another point also beyond a doubt. Afghanistan is the highway by which these styles came, and it is the country in which to seek for knowledge regarding them. There are vast regions beyond Afghanistan of which we literally know nothing. These localities must be visited. Armies may march and fight in Central Asia, and archæologists must march also, and explore. They at least must conquer. When Afghanistan is archæologically ours, the students of Indian antiquities will be a long way on towards meeting the explorers of Nineveh and Babylon, and I hope that the day is not far distant when they may shake hands, and compare notes, somewhere about Ispahan, Yezd, or Naishapoor.

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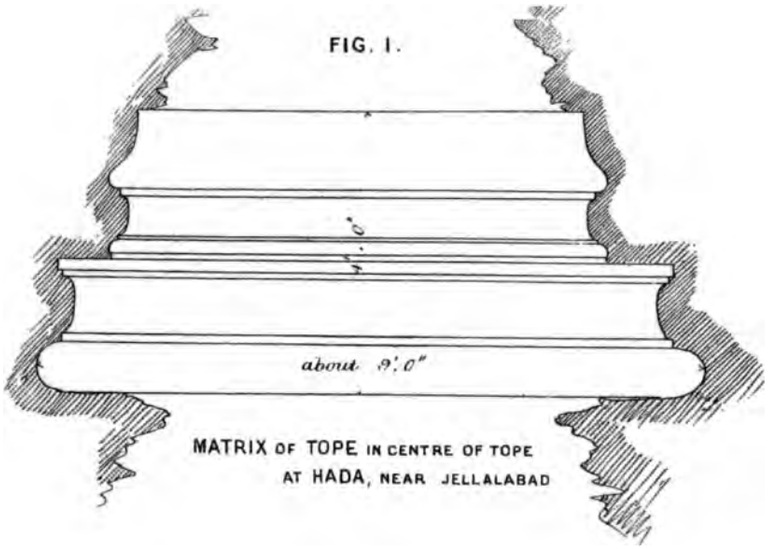
* See pl. VII., fig. 3, at A.

† Lady Sale mentions them in her Journal. See also Masson's Narrative, vol. ii. p. 386.

‡ See pl. VII., fig. 3.

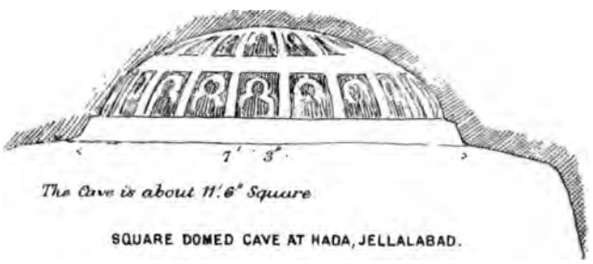
§ See pl. VII., fig. 6. The ground colour of the circle in which the figure sits is of an emerald green. It should also be noticed that the person represented sits on a chair, and there is no Gudhi, or Pal—as in India. Chairs are still used by the inhabitants of Kafiristan, showing the possibility of Buddhist, or pre-Buddhist, ideas and customs yet existing in that country.

FIG. 1.



MATRIX OF TOPE IN CENTRE OF TOPE AT HADA, NEAR JELLALABAD

FIG. 5



SQUARE DOMED CAVE AT HADA, JELLALABAD.

FIG. 2

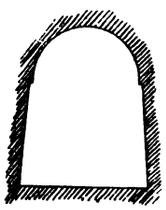
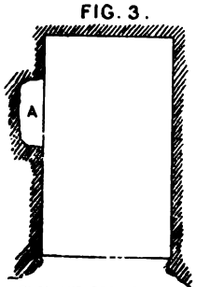
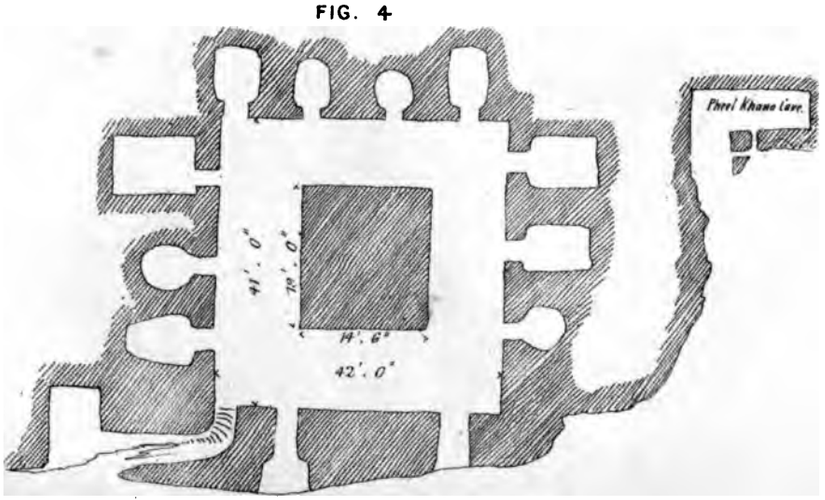


FIG. 3.



PLAN AND SECTION OF ORDINARY CAVE IN JELLALABAD VALLEY

FIG. 4



VIHARA CAVE AT THE PHEEL KHANA CAVE, JELLALABAD VALLEY.

FIG. 6.

FRESCO ON SMALL CAVE AT HADA.

William Simpson

Photo-Lith.ª by C.F Kell Castle St Holborn, E.C.

DISCUSSION.

JAMES FERGUSSON, F.R.S., *Past Vice-President.*—This interesting Paper, with which Mr. Simpson has favoured us, covers such a vast extent of ground, and opens up so many questions, that it is extremely difficult to follow him, and almost impossible to do justice to it, in a discussion, limited as this must be not only by the time of night, but by the means of illustration which are available. When printed, this Paper will be a most valuable contribution to our knowledge of the subject of which it treats. The only information we have hitherto had regarding the topes about Jellalabad was from a Mr. Masson, who opened a considerable number of them in search for coins, in which he was very successful. His results with drawings of the topes were published by the late Professor Wilson in his work called Ariana Antiqua, in 1841. But Mr. Masson was not an artist, still less an architect, and his drawings gave little or no information regarding the form, still less regarding the style in which these buildings were erected. Mr. Simpson, on the contrary, is both the one and the other. He has a wonderfully correct eye for details, and a marvellously facile pencil for delineating them, and his plans are really the first we have ever possessed, while his restorations are done with a judgment and knowledge of which we have hitherto had no experience, as applied to the subject. Besides these advantages he has brought home photographs made on the spot, and others from the vast collection of antiquities from the Peshawur valley, which fill the Lahore Museum to overflowing. And in addition to all this he has brought home specimens of the antiquities themselves, which are now on the table before us. Besides all these advantages, Mr. Simpson has considerable previous experience in India and Tibet of the form of Buddhist architecture, and consequently approached the investigation of these ruins with advantages possessed by few among those who have hitherto made the attempt. Perhaps the most striking and important fact brought to light by Mr. Simpson's drawings, when combined with the recent discoveries in the Peshawur valley, is the singularly classical character both of the architecture and of the sculpture of the valley of the Kabul river. Nine-tenths of the capitals of the pillars and pilasters are Corinthian, and the bases and mouldings generally are such as are most unmistakeably derived from the far west. It is true that with these there are found a certain number of bell-shaped capitals surmounted by double animals which look like a reminiscence of the pillars of Persepolis, and these, as Mr. Simpson remarks, are found in the caves at Karli and elsewhere in India. The similarity is however so remote that it is hardly sufficient to sustain Mr. Simpson's assertion that every form of art was imported into India and nothing ever came out of it. This quasi-Persepolitan art in India is evidently derived from some wooden prototype, and may have been practised simultaneously in the two countries, without its being clear that the one borrowed its forms from the other. But be this as it may, it is quite certain that the classical style, with which it is mixed, never penetrated—except sporadically—beyond the Indus. It was there met by a style with which we are perfectly familiar in the third century before Christ, and from that time onwards. It is perfectly Indian and original, and if it never was carried westward out of India, it certainly never was imported. It was invented and perfected in India and spread

eastward through the whole Indo-Chinese countries, though Mr. Simpson is quite correct in saying it never spread from India westward. The most interesting and most important point raised by the Paper is in reality the inquiry whence this classical art came into the valley of the Kabul river, and when it first appeared there. The first and most obvious suggestion is that it was left there by the Greeks, who established the kingdom of Bactria immediately after the glorious raid of Alexander, and who no doubt left buildings and statues in the country they held for a century and a half. No remains of this art have however been yet found in the valley. Everything that has been discovered is clearly and essentially Buddhist, and Buddhism it is generally admitted was introduced into the country by Kanishka, a king who reigned at the end of the first century after Christ. An interval therefore of between two and three centuries must have elapsed between the fall of the Bactrian kingdom and the earliest building we know; and it is difficult to understand a school of art retaining its traditions in a foreign country for such a lengthened period. It is a curious confirmation of this, that, as mentioned by Wilson in his Ariana Antiqua, not one coin of a Bactrian king has been found among the hundreds that have been discovered in the topes, while Mr. Simpson himself found coins of Trajan, Domitian and Hadrian; and Mr. Masson others of the Emperor Theodosius (408 A.D.) and Martian and Leo (474 A.D.) in topes erected subsequently to these dates, but all of which in so far as there architecture can be made out are of the same type. In addition to this it may be mentioned that the Corinthian order, found in the valley of the Kabul river, is not the Grecian order, or at all like it. It is not even the Roman order as practised in the third century at Palmyra—the nearest point. We know exactly what was done there in the times of Zenobia and Aurelian, and it was very like the order found in the Portico of the Pantheon at Rome in the time of Augustus. The order here is essentially Byzantine, such as we find in churches at Salonica and in Asia Minor after the time of Constantine, and it is coupled with a form of Buddhism that in India did not exist before the third or fourth century. In India proper there is no statue of Buddha in any of his conventional attitudes which can possibly be dated before 100 A.D. In these Jellalabad topes figures of him in every mode and attitude occur by dozens, it may be said by hundreds; such a multiplication of images is not found in India before the fourth or fifth century. It may have been introduced earlier into the valley of the Kabul river, but how much earlier must be left for future investigation. Meanwhile, however, I am very much of the opinion, just expressed by Mr. Simpson, that though from the existence, in its cella, of Roman coins of Hadrian, the Ahin Posh Tope which he opened cannot be earlier than the second century A.D., he is inclined to think it may have been two or three centuries later. If this is so it follows almost inevitably that the bulk of the Buddhist ruins in the valley of the Kabul river is more modern than has generally been assumed, and may date from the second or third to the sixth and seventh centuries of our era. It is of course very difficult to understand, in the present state of our knowledge, how any Roman or Byzantine influence can have extended to this remote province, across and beyond the Parthian and Sassanian kingdoms, after the time of Valerian—say 260 A.D.—but this is just one of those questions where the testimony of art, and especially of architecture, becomes so valuable, and renders such a subject as that brought before us this evening by Mr. Simpson so especially interesting. The fact is certain that there exists, in the valley of the Kabul river, a number of buildings ornamented with pillars

and pilasters of the Corinthian order which does not, and never did, extend into India; and also that that order resembles far more one used in the Byzantine empire in the fourth and fifth centuries than anything found before. It is equally certain that it is combined with a school of sculpture so similar to one of the same age that if specimens of it were placed in the Vatican or Lateran Museums, and labelled as belonging to the Byzantine school of the fifth century, few would detect the difference. There is indeed one specimen on the table, which, if photographed to a small scale, and handed round with an ivory of Valentinian, few would be able to detect from either the architecture or the art that they were not manufactured at the same time and place. The costume of Buddha would betray the difference, but not the style of execution. I wish I could venture to hope that this Paper will induce others to turn their attention to a subject which is full of interest, but at the same time, it must be confessed, full of difficulty. It will require the earnest attention of many earnest searchers after truth, before a solution, which will be satisfactory to all, will be obtained of the many problems involved in it. At the same time it is to be feared that the materials hardly exist in this country, to enable the question to be studied with the fullness it requires. Six months ago the Indian Museum possessed a collection that went far towards supplying that want, and further materials might easily have been obtained from India at very little trouble or expense. Since then that Collection has been broken up and dispersed, and at present no means exist in this country sufficient to enable these questions to be scientifically examined. Meanwhile, however, coins and photographs are available, and these, with such details as Mr. Simpson has brought before us this evening, and it may be hoped others will supplement, will go far towards enabling scholars to appreciate the importance and to understand the bearing of the many questions involved in the study of antiquities from the valley of the Kabul river in Afghanistan and Peshawur.

Col. Yule, C.B.—As Mr. Fergusson has said, in following a Paper like this, so full of matter and touching so many points, it is possible only to catch hold of one or two points, without being able to enter into any systematic discussion of the whole subject. What Mr. Fergusson has just said as to the resemblance of the sculptures on the table to Byzantine work, and especially to Byzantine ivories, is very striking, and entirely new to me. I should have been disposed to adhere to the old view—if we can call anything an old view in regard to a subject which is so recent—that these traces of Greek art were connected with the existence of a Greek monarchy in that region, that is in the valley of the Kabul river and the provinces immediately adjoining it. For, if we look at the coinage which has revealed the greater part of what we know of the ancient history of that region until now, when we are beginning to derive materials also from remains of architecture, we find, first, coins of pure Greek art, or tolerably pure Greek art, struck by kings who actually were Greeks. Next, when the Greek monarchy in that region had been overthrown by barbarians from Central Asia, we find that they inherited or picked up a certain amount of the art of the Greeks, whom they had overthrown, and imitated their coins. But their coinage gradually became barbarised, and the Greek letters gradually became corrupted, until they are scarcely legible as such, and vanish at last entirely into barbarism. Thus, also, I should have thought it probable that architecture, derived from the same source and the same period, might have run an analogous course, which would account for the fact that we trace first the Corinthian decoration and the

sculpture gradually becoming corrupted, but both still retaining a certain flavour of Greek, until finally that flavour vanishes into barbarism, or at least into the barbaresque, and into what has become essentially a Hindoo style of art. I only mention this as the view I had before I heard what Mr. Fergusson said. Most things that he says are striking and suggestive, and one at least hesitates to oppose them.* I do not know whether the audience clearly understand where this locality is. Jellalabad and the other places mentioned are in the valley of the Kabul river which comes running down from the west to the east, entering the Indus, which was approximately our frontier before the war; and it was in accompanying the first expedition, the year before last, that Mr. Simpson performed the most meritorious service in examining these antiquities. Now this valley of the Kabul river was, as I said, one of the chief seats of that Greek monarchy, and after that it was the seat of various semi-barbarian monarchies, but as far as we can understand about the population and their character, they were essentially Indian the country in fact was Indian. Though now it is not Indian, nor any part of India, yet up to probably the eighth or ninth century that country was a part of India, inhabited by Indian people, with Indian customs and the Indian religion. At that time it was, as these remains show, a valley rife with population, art and civilization. But it afterwards became a highway of Mahomedan conquest, and then at a late date, for about a century, the scene of almost annual inroads of the Mongols and Tartars, till at last the country became desolate. We have two striking pictures of it with a long interval between. There is one given us by that Chinese pilgrim, Hiouen Thsang, whom Mr. Simpson so often quoted, who travelled from China to India for devout purposes in the early part of the seventh century, travelling through Central Asia and Bactria, and entering India by the Kabul valley. He describes the splendid edifices which then existed in the valley of Peshawur. He describes a tope 700 feet high! This may or may not have been a true measurement, but whether such the tope was very high and imposing, it was covered with gold, and crowned with those splendid umbrellas and gilded bells hanging from them. Another Chinese traveller describes enthusiastically the bells of the tope—these golden bells—as "tinkling in the morning wind."† There were probably many of these buildings around Peshawur, which is now our great frontier post in that quarter. At present, as Mr. Simpson has said, there is nothing like architecture in the country. All this civilization was swept away. For a long time the land lay desolate,

* One of Mr. Fergusson's grounds for doubting the view contained in the preceding sentences is that we have no architectural remains of this character dating earlier than the first century A.D., or say two centuries after the downfall of the Greco-Bactrian monarchy, whilst most of them are probably two or four centuries later in origin. But Indian sculptors who could carve such forms as we know would have built or sculptured in a similar Greek character. So that whether we find their remains or not (and how much has yet to be explored!) these buildings must surely be existed. May not the development of a style as like Byzantine as in some respects have been an independent result of analogous causes acting on the same original motive. Mr. E. Brandreth has shown in the Asiatic Society the extraordinary analogies which exist between the forms in which Sanskrit has broken up into the various Prakrit languages of modern India, and the way that Latin broke up into the various Romance languages of modern Europe. These analogies are not only minute in some respects as between the Prakrit and the Romance languages, but even as the modern Prakrit shaping is towards from Sanskrit is often analogous to Italian inflections from Latin, whilst another is in an exact analogy to French. These analogies are more extraordinary than the resemblance which Mr. Fergusson points out between Buddhist and Byzantine sculptures. But no question of imitation is here possible.—E. T.

† "A curious thing about the water we lit up with morning gun, whilst the gentle breeze of morning rises the precious bells of India with a pleasing sound." Beal's Buddhist Pilgrims, p. 38.

insomuch that the great Sultan Baber, the Moghul conqueror of India in the sixteenth century, describes how he went to hunt the rhinoceros in this same Peshawur valley, a place which then had become the haunt of that animal—an animal which is not now found within a thousand miles of Peshawur. Then came in gradually the Afghans from the south and south-west, and occupied the land,—a people without the rudiments of art, without anything even like decent brickwork or carpentry. That is one of the things about which it occurred to me to say something. I cannot attempt to make my remarks connected, but I will take up another point. Mr. Simpson often mentioned the word "vihāra," and that he didn't explain it, was, I think, hardly fair. The word means a monastery, the dwelling of the ecclesiastics, which was generally attached to, or in connection with, those topes, these latter being in fact not only places, but objects of worship. That word "vihāra" affords an instance of the extraordinary spread and influence of Indian religion. You have all heard of Lord Clive's original acquisition for the East India Company of the three Provinces of "Bengal, Behar and Orissa." Now Behar Province takes its name from a town called by the same name, which derived its existence and its title from a great Buddhist vihara which once stood there. Again, we had last year in England as a visitor the young Maharajah of Kooch Behar. Well, his territory also takes its name from another great Buddhist monastery which existed in it probably 1200 years ago. You may have heard of the great alarm last year of the people in Bombay lest the great dam of the water works which supply the city with water should burst. That dam is called the Vehār Dam, and the name of this again is derived from the fact that it stands near the ancient site of another great vihara or monastery. If, once more, we go further up the valley of Kabul, cross the mountains and cross the Oxus, we get to the city of Bokhara. That city again, we learn from old Arab writers, was called so, because in Pagan times it was the seat of a college, or company of learned men, that is to say, it was a vihara. That also must have been a Buddhist monastery. Now this gives you some idea of the former enormous influence and spread of the Buddhist religion from India, upon the face of which vast country no Buddhist now exists. There is no real Buddhist now existing in continental India—not at least in our territory,—and yet this religion not only has left its gigantic footsteps over India itself, but once spread from India over all the adjoining countries and islands, in several of which it still survives. Once more, I was much struck with what Mr. Simpson said of the persistence, in the region of which he speaks, of tomb-worship, in spite of all the change of external forms. The ancient inhabitants of the Jellalabad valley worshipped at their tope, which was in effect the shrine of a dead saint. And now the Mahomedans again erect their little ziārat, probably upon the same hill, and worship there at the shrine of *their* dead saints. I may conclude by mentioning that this sort of saint-worship is very prevalent among the very wildest and most ruthless robbers of those Afghan valleys. Indeed it is said to be especially dangerous for a holy man to travel among them, because they are pretty sure to knock him on the head, in order that they may have a shrine handy to worship at.

THE PRESIDENT.—I will only say in the name of the Institute how grateful we are for a Paper of this importance and novelty. I think it is particularly appropriate that it should have been read within these walls. A thought has been suggested to me with regard to the architectural character of these remains, and it will probably occur to many others that the character of the remains indicates that the style has not come directly from the Greek, but

that it is Roman rather than Greek in its derivation. I hasten to propose a vote of thanks to Mr. Simpson for the excellent Paper he has read.

The vote of thanks, put from the Chair, was carried by acclamation.

WILLIAM SIMPSON, F.R.G.S.—I acknowledge, most heartily, your kindness in the manner of passing this vote of thanks, and independently of the value of your approbation I wish to add how pleased I am to have read this Paper to-night before you. The geography referred to in my Paper deals simply with the banks of the Indus; it is only necessary to keep in view the two sides of that river, and the valley of Jellalabad, with which you are all no doubt familiar now as part of our new frontier. Regarding one of the styles I have spoken of, whether it came first from the Greek influence at an early, or a later period, that is, I am afraid, an uncertain matter upon which, in our present state of knowledge, to give an opinion. The connection may have continued between Bactria and the west from the Greek period down to the later Roman and Byzantine dates; that is not impossible. There is undoubtedly a great resemblance between the sculptures exhibited here to-night, as Mr. Fergusson has pointed out, and the art of the time he mentions. There is quite sufficient evidence, however, to show that the Greek influence came into Afghanistan; probably it did not come down in that direction for some time, during which it remained in Bactria, and only moved towards the Indus when splendid buildings were required. The time it took the Greek to become Roman, and then the Roman to change on the one side to Saracenic and on the other to mediæval, was quite as long a period as that we are dealing with in the more eastern part of the world—at least I think the time in each case is about the same, and that they may be compared. There may be remains yet existing about Bactria which would throw light on these subjects, and when I went out it was one of the objects I had in view to get up in that direction. I had a great desire to visit a spot a hundred miles further north than Kabul, that is Bamian, but I found it was impossible, and came back rather a disappointed man in consequence. The events which afterwards took place at the Residency in Kabul have modified my feelings in regard to this.

7.

[*From the* PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, vol. 164, pt. 2.]

XIV. *On the Quantitative Analysis of certain Alloys by means of the Spectroscope.*

By J. NORMAN LOCKYER, *F.R.S., and* W. CHANDLER ROBERTS, *Chemist of the Mint.*

Received November 20,—Read November 27, 1873.

IN certain researches on Spectrum-Analysis, the results of which have already been communicated by one of us to the Royal Society, it has been shown that the spectroscope may be employed to distinguish minute differences in the composition of certain alloys. We have therefore instituted a series of experiments with the view to ascertain the degree of accuracy of which the method is capable, and now submit the results which we have already obtained.

In the researches above referred to, an electric-spark-current was used to volatilize the alloy under examination, and the image of the spark was thrown by means of a lens on the slit of a spectroscope; the phenomena observed indicated that a change in the percentage of any constituent of a metallic alloy ordinarily causes a change in the character of lines exhibited in the resulting spectrum, in length, brightness, or thickness; and the percentages of the constituents, it was stated, might be determined by comparison with the spectra of pieces of metal of known composition.

It may be remarked that changes are exhibited in the spectra in various ways, thus:—

1. Changes in the lengths of lines of one constituent.

2. Changes in the position of the point at which lines belonging to different metals in the alloy show equal brightness or thickness.

3. Changes in the relative lengths of a pair of lines belonging severally to the constituents of the alloy.

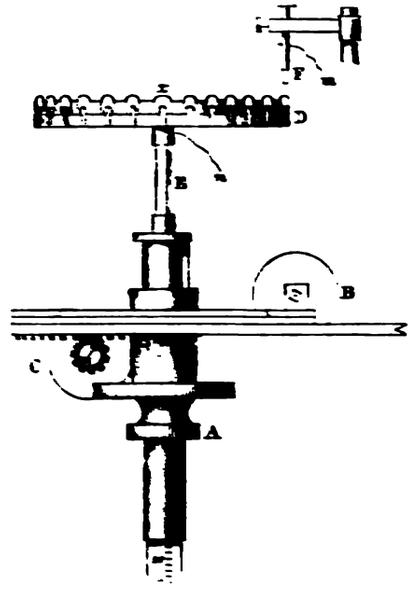
Any of the above changes may give the requisite information, and all are due to the same cause, which evidently is the difference of alloys as regards volatility. Thus in the case of gold and copper, the former being less volatile than the latter, there will be a minimum of metallic vapour with pure gold and a maximum with pure copper; and when alloys are employed, there will be a regular gradation between these two limits.

In the experiments about to be detailed, unknown alloys and check pieces of known composition having been arranged on a suitable stand (as shown in the diagram, p. 496), they were in turn brought immediately under the fixed electrode F (of aluminium or iridio-platinum).

We were soon convinced that it was necessary to regulate with extreme accuracy the length of the spark by which the incandescent vapour of the alloy was produced; and

the following experiments were made with a view to determine what details of manipulation would give the most satisfactory results.

In the first attempts a fragment of the alloy of a more or less irregular shape was simply held in a suitable clip, and a spark-current passed from the alloy to a similar



A. Milled head of elevating-screw.
B. C. Horizontal adjusting-screws.
D. Revolving table.
E. Insulating glass rod.
F. Fixed terminal.
x. Series of assay-pieces.
m, *n*. Wires from induction-coil.

fragment of aluminium or other metal. We then adopted a method orally suggested to one of us by Professor STOKES, which consists in the passage of the spark-current in a vertical line across the shortest distance between two cylinders arranged in a horizontal position, with their axes at right angles to each other.

The use of these cylinders was attended with many difficulties, and we substituted for them strips of metal cut in the form indicated in the figure (at *x*).

The distance between the poles was at first adjusted by a gauge, and subsequently by a cathetometer; but the most accurate results were obtained by placing the portion of alloy in the field of a microscope furnished with a 3- or 4-inch objective, a simple mechanical arrangement, shown above, bringing the surface from which the spark would pass to the point of intersection of two spider-lines in the eyepiece of the microscope.

We were careful to select alloys which were homogeneous in character; and our attention was first devoted to observations on the zinc-cadmium alloy, one of a series of

alloys termed by MATTHIESSEN "solidified solutions of one metal in another." We next operated upon the gold-copper alloy, as its molecular arrangement appeared to render it peculiarly suited for the purpose of the research, the use of this alloy being attended with the additional advantage that the ordinary method of assay has rendered it possible to determine its composition with accuracy to the $\frac{1}{10,000}$ part of the original weight of the assay-piece, a degree of precision which will appear remarkable to all who are familiar with the ordinary methods of quantitative analysis.

We give in the accompanying curves (Plate XLI.) the results of our experiments with alloys of known composition, in which experiments the precautions to which we have referred have been taken. The results are represented graphically, the coordinates being the composition of the alloys as determined by the ordinary method of assay, and by the varying points of equal brightness as measured on the micrometer-scale of the lines at the wave-lengths stated in the diagrams. The micrometer is fixed to the eyepiece end of the observing-telescope. It is an ordinary wire-micrometer with movable horizontal wires. The micrometer-readings are represented by spots placed opposite the compositions as determined in the ordinary manner, a mean curve being subsequently constructed.

We have found that there are several variations possible in the method of observation, and we are yet uncertain which of these variations will afford the most satisfactory results.

Our method of procedure was upon each occasion to prepare such a curve by means of accurately known standards; and having this curve, to determine, by means of the micrometer-readings, the positions which various specimens of unknown composition would occupy on it. By carrying the eye from the curve to the side on which, as in those communicated to the Society, the parting assay determinations were shown, we were enabled to compare the places assigned to the specimens, on the curve, by the spectroscope with those determined by the parting assay which we then learnt for the first time. We do not think it necessary to give these curves, but may say that, as the result of many series of experiments with alloys of unknown composition, the difference between the spectroscopic and parting assays was but small so long as the conditions under which we experimented continued to be uniform.

Descriptions of Curves.

Curve No. 1.

A number of alloys of zinc and cadmium were synthetically prepared, and from these a series of five, the percentages of cadmium in which increased by 1 per cent. from 50 per cent. to 54 per cent., were carefully selected for the experiments. It is interesting to note that both the metals employed in the alloy are very fusible (zinc melting at 433° C. and cadmium at 228° C.); and observations by means of the spectroscope at once enabled us to arrange these alloys in their correct order.

Curve 2.

This comprises a series of alloys ranging from 900·0 to 922·5 parts of gold in 1000 of the alloy. It was obtained by measurements made by placing the micrometer-wires in a vertical position and measuring the base of the lowest visible portions of the spectroscopic lines under examination, a method which appeared to be better suited to wide ranges than observations made in the upper portions of the spectral lines; these latter were, however, found more suited to the study of narrow ranges, such as that shown in Curve 3. We should remark that, at this early stage of our inquiry, our attention was mainly devoted to ascertaining whether the curves would be continuous, and to determining at what point a curve deduced from any given lines in the spectrum would cease to be sensitive.

Curve 3.

The Curve 3 was constructed by means of observations made upon several specimens of gold-copper alloy, the composition of which had been determined to the $\frac{1}{10,000}$ part in the ordinary manner. Micrometer-readings for these specimens were taken, which, together with their known approximate compositions, furnished the coordinates to the curve.

It will be seen at a glance that with regard to the lower part of the curve a change of composition of $\frac{1}{10,000}$ gives a much greater change in the micrometer-readings than it does in the upper part. It is also to be remarked that, as in this more sensitive portion a change of $\frac{1}{10,000}$ part is represented by a change of 200 in the micrometer-readings, a true mean curve can only be constructed when the actual composition of the alloy is stated with much greater accuracy than that afforded by the present method of assay.

We should observe that as in several cases duplicate and even triplicate readings were made with the same specimens, the number of spots placed opposite any figure in the vertical column does not necessarily indicate the number of pieces of that composition under examination. If we examine the Mint specimens, of which the composition is stated to be 916·4, it is seen that the maximum departure from the curve is less than $\frac{1}{20,000}$ part; and in this case it is impossible to say that any error has been made by the spectroscope, because, were the composition of all the alloys in question to be what the spectroscope states them to be, they would still be called 916·4 on the parting assay. Again, if we consider the specimens 916·6, it will be seen that while in those two with micrometer-readings 150 the departure is not more than that previously stated, $\frac{1}{20,000}$ part, on the other hand the composition of the two the micrometer-readings of which were 250 would carry them into a region of the curve which would spectroscopically indicate their composition to be less than 916·5. The departure in this case was so great that it was considered advisable to make a fresh determination of their composition by the ordinary method; and it was satisfactory to find that the parting assay determination, as revised, was almost identical with that given by the spectroscope.

Curve 4.

The range of alloys is the same as those given in the preceding curve; but the method used was that employed in obtaining Curve 2, and it is interesting as illustrating the change introduced into the form of the curve by varying the method by which the spectral lines were observed.

Practical Considerations.

It is impossible to foresee to what analytical operations the new method may be found to be applicable; but as the experiments hitherto have been mainly directed towards the development of a new method of assaying gold, it is advisable that attention should be limited to the relative advantages of the old and new methods.

We ascertained by careful experiment that the amount of alloy actually volatilized during an observation in no case exceeds 0·0001 grm.; and it is interesting to compare this with the amount of metal usually employed in assaying gold, which varies from 0·5 to 1 grm.

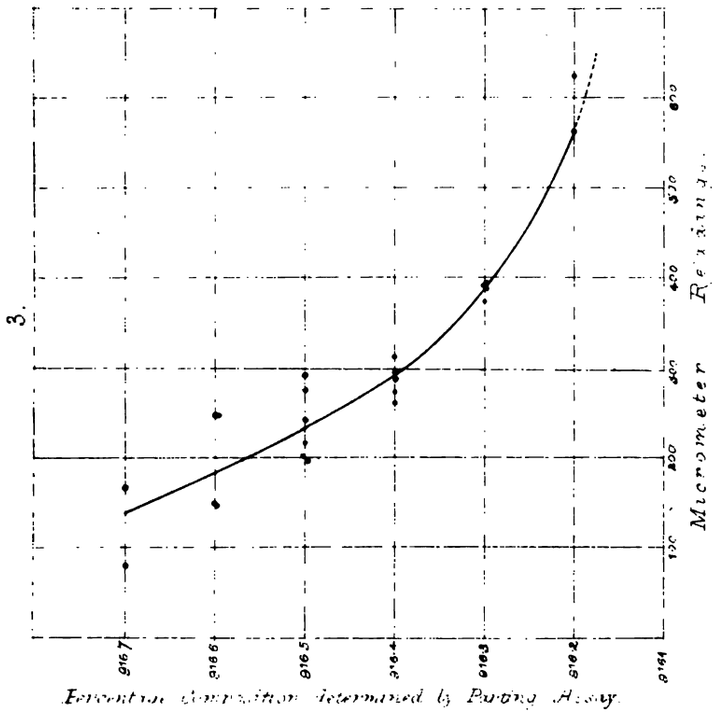
It may be objected that the amount of metal employed in the new method is very small; but granting the accuracy of the method and the homogeneity of the alloy, there is of course no reason why the composition of a gold ingot may not be ascertained by it as accurately as by the old method.

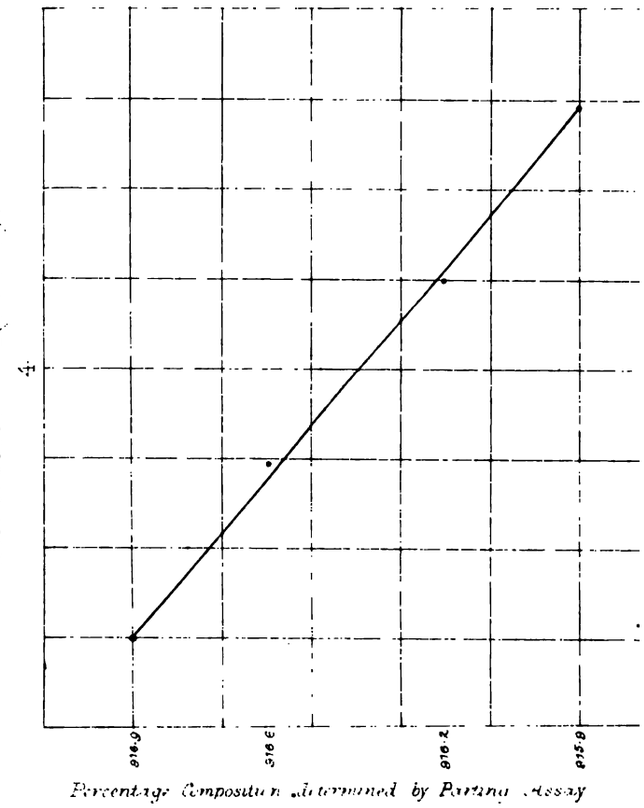
It is now well known, as previously mentioned, that the existing method is usually accurate to the $\frac{1}{10,000}$ part of the portion of metal operated upon, the process possessing in addition to its accuracy many incidental advantages, not the least of which is the possibility which it affords of detecting, at different stages of the work, the presence of metallic impurities, such as iridium.

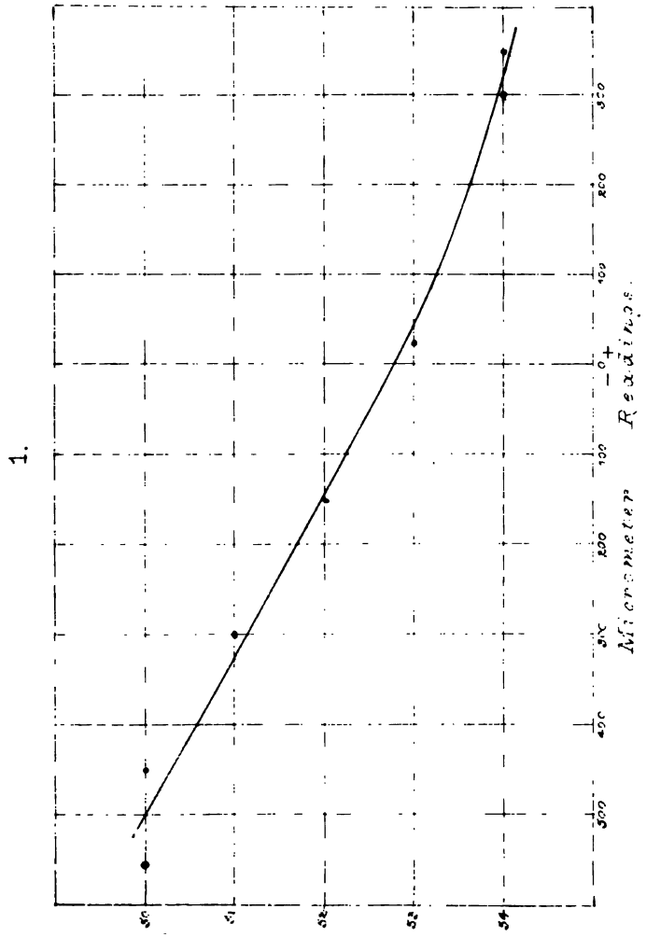
On the other hand, it should be observed that the method now in use comprises six distinct operations, and two hours are occupied in ascertaining the final result of the assay; and as it is frequently important to determine the value of an ingot of gold with rapidity, it will be obvious that the new method possesses marked advantages in this respect, for by its aid a result may be obtained in a few minutes.

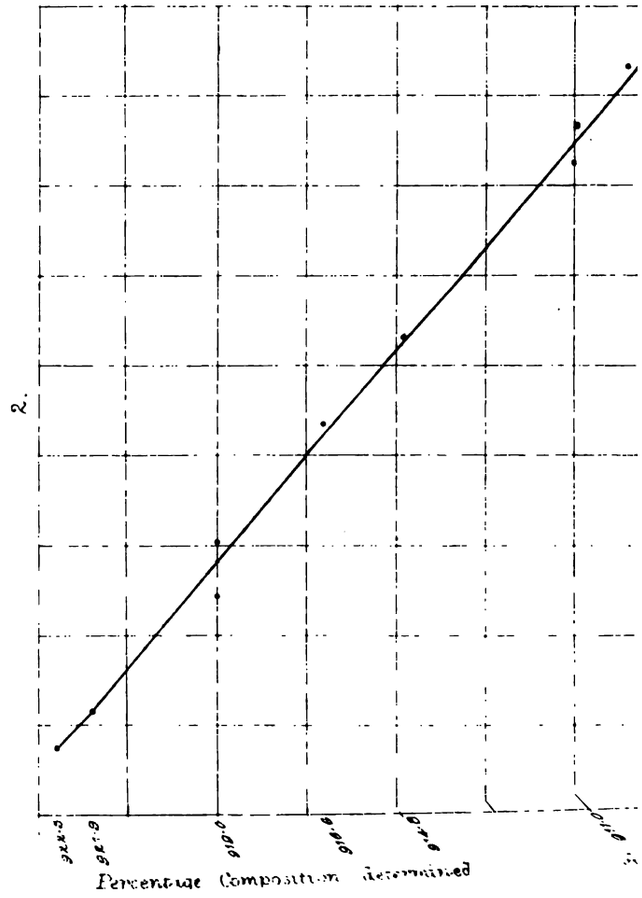
In conclusion, we would submit that experience alone can show whether this new process may be made as trustworthy as the existing method; and we would draw attention to the fact that hitherto there has not been absolute identity in the conditions under which the several experiments were made; for instance, the intensity of the current employed to volatilize the metal varied from time to time; and this, together with other defects, mainly arose from the fact that we have as yet considered the problem solely from its scientific aspect, and have not provided ourselves with instruments well adapted for satisfying all the conditions which may arise in practice.

Whether this new method be found preferable to the old one or not, the fact has been clearly established that it is possible to detect, by its means, differences in the composition of the gold-copper alloy as minute as the $\frac{1}{10,000}$ part of the whole mass.


3.
Micrometer Readings.
Percentage Composition determined by Parting Assay.


4.
Percentage Composition determined by Parting Assay


1.
Micrometer Readings.


2.
Percentage Composition determined

IV. *On the Lingual Dentition of some West-Indian Gasteropoda.*

By R. J. Lechmere Guppy, *Esq.*, *F.G.S.*, *and* Jabez Hogg, *Esq.*, *F.L.S.*, *M.R.C.S.L. &c.*

(Plate XI.)

Read June 21st, 1866.

SINCE the investigations of Lovén into the lingual dentition of the glossophorous Mollusca, various observers have studied the subject, with great advantage to our knowledge of the affinities of those animals. Thus we find, amongst other changes, that it has been necessary to remove the Proserpinadæ from the neighbourhood of the Cyclophoridæ, to which they were formerly supposed to be nearly related, and to place them in a more natural position near the Neritidæ. That these investigations are of great value is also shown by the light which has been shed on the true position of *Aporrhais*, supposed by so great a naturalist as Professor Forbes to be akin to the Cerithiidæ, but which is shown by its dentition to belong to the Strombidæ. When once we have thus ascertained the natural position of a genus whose relations are otherwise somewhat doubtful, it is surprising how the characters of the shell, perhaps misunderstood before, concur to bear out the affinities indicated by the teeth. Thus the young *Aporrhais* resembles a young *Strombus* or *Rostellaria*; and *Ceres* and *Proserpina* have evidently characters which approach them to *Nerita*. Observations on *Helicina*, published in 1864, by one of the authors, showed the relationship of that genus to *Nerita*, to which indeed in its dentition it bears a stronger resemblance than does even *Ceres*. These views have been confirmed, independently, by several authors.

It is our object, in the present paper, to make known some new forms of lingual dentition, some of which, it will be observed, point the way to further reforms in our classification of the Gasteropoda *.

* Dr. J. Gray, F.R.S. ('Annals of Natural History,' ser. 2, vol. x. p. 413), writes:—"One result of the study of these papers (Lovén's "On the Tongues of Mollusca") and the examination of the tongues of several mollusks has been to establish more firmly the theory which I have long entertained, that no species of gasteropodous molluscous animal can be properly placed in the system unless we are enabled to examine the animal, the shell, the operculum, and the structure of its tongue; and as none of these parts but the shell can be examined in the fossil species, their position in the various genera must be always attended with more or less uncertainty."

Professor Huxley very properly objects to the use of the commonly-accepted term *tongue* for the tooth-bearing membrane of the mollusca, and he appropriately designates it "the odontophore."

"The *odontophore* consists essentially of a cartilaginous strap, which bears a long series of transversely-disposed teeth. The ends of the strap are connected with muscles attached to the upper and lower surface of the hinder extremities of the cartilaginous cushion; and these muscles, by their alternate contractions, cause the toothed strap to work, backwards and forwards, over the end of the pulley formed by its anterior end. The strap consequently acts after the fashion of a chain-saw (*rather of a rasp*?) upon any substance to which it is applied; and the resulting wear and tear of its anterior teeth are made good by the incessant development of new teeth in the secreting sac in which the hinder end of the strap is lodged. Besides the chainsaw-like motion of the strap, the odontophore may be capable of a licking or scraping action as a whole."—*Huxley's Elements of Comparative Anatomy*, p. 36.

We shall first premise that the teeth on the dental band of the Mollusca are mostly disposed in longitudinal series. In the Pulmonata there is usually a single median row, the laterals on each side being broad and similar. But in most of the other groups the teeth are arranged in three, five, or seven dissimilar series. Taking *Nerita* or *Helicina* as a type, we designate as *laterals* the broad teeth on each side of the median row, the numerous small teeth on the outside of the band being known as *pleuræ*; and the teeth on this are termed *uncini*. The latter are found only in certain groups. Most of the Mollusca mentioned in this paper have been recently described or enumerated in the 'Annals and Magazine of Natural History'*, where further particulars as to their habits and organization will be found.

In the genus *Bulimus* we have a dentition resembling in general characters that of *Helix*—that is to say, a broad dental band with numerous similar teeth. But the forms of the teeth themselves are very varied; and it is a subject for inquiry how far the divisions proposed by zoologists are borne out by this part of the organization. In *Bulimus oblongus* the teeth are subquadrate, with simple obtuse cusps, the laterals differing but slightly in shape and size from the medians. This species is interesting on account of the peculiar frontal appendages, first described by D'Orbigny, which recall to our minds those of the *Nautilus*, though the resemblance is not perhaps great; still it is a morphological resemblance. We find, too, that this mollusk has mandibles somewhat resembling those of a Cephalopod.

The teeth of *Bulimus zebra* have considerable resemblance to the preceding. The animal has no peculiar frontal appendages, like those of *B. oblongus*; and its mandible is not different from those of other members of the group.

Bulimus virgulatus, a mollusk of the Antilles, presents a different type. The teeth are in divergent rows, the medians small, with a round reflexed tricuspid point, the laterals, on subquadrate bases, with denticulate reflexed edges, the cusp on the inner side being rather long. The denticles appear to be 3–4 in number, of which two only are usually seen at one view with the microscope.

The teeth of *Bulimus multifasciatus* (Plate XI. fig. 1), *B. immaculatus*, and *B. aureolus* are so nearly alike, that one description will serve for them all. In general arrangement they are like the preceding species'; but the medians are minute, and the laterals are armed with three long acute cusps, which frequently escape observation, being as pellucid as glass. We have ourselves overlooked them; and owing to this the teeth of this species have on former occasions been wrongly described.

In *Bulimus caracasensis* the medians, so extremely difficult to make out from their minuteness, are simple, the laterals symmetrical; that is, they are equal-sided, differing in this respect from those of most other mollusks. We have observed that several of the species classed under *Bulimus* present this form of teeth, which is also found in *Stenogyra octona* (fig. 2). In *Tornatellina lamellata* (fig. 5) the dentition somewhat resembles that of *Bulimus multifasciatus*, the laterals having long acute pellucid cusps.

In *Plecocheilus auris-sciuri* (fig. 4), a species very near *P. glaber*, the median row is

* Ser. 3, vol. xiv. p. 243, and vol. xvii. p. 42.

remarkable for the great length of the imbricating pellucid cusps. The laterals seem also to have a similar cusp; but it appears to be more often absent than present: as, however, their extreme fragility renders them very likely to be broken off, it is in all probability due to this cause that they are so often found wanting.

Macroceramus signatus (fig. 7) resembles *Helix* more than any of the *Bulimi* here described in its dentition. The medians are elongate, with a single obtuse rounded cusp; the laterals have two round subequal cusps, of which the inner one is situate on the side of the tooth.

Pupa striatella, a species inhabiting Porto Rico and other West-Indian islands, has a dentition somewhat resembling that of *Bulimus*. The teeth are obtusely tricuspid, the medians not any smaller than the laterals. *Succinea approximans* has teeth possessing characters of *Bulimus*, but differing in details, as will be seen by the specimens. In *Veronicella* (*Vaginulus*) *Sloanei* the medians are small, and the laterals as well as the medians are tricuspid. This dentition does not resemble that of *Oncidium*, with which the genus has hitherto been associated.

In *Physa rivalis* the teeth are slender, and bear no great resemblance to those of any of the terrestrial forms. In *Planorbis terversanus* the median teeth are largest, and have three acute points, of which the middle one is the smallest. The laterals have three acute points, of which the outer one is largest. The edges of the teeth are not reflexed. Amongst the marine mollusca which have teeth somewhat of this shape are *Voluta* and *Marginella*; but these have very much fewer teeth, with usually more numerous denticles.

Marginella cærulescens (fig. 3) has a small subquadrate band of acute pellucid teeth, the medians of which are shortest; the laterals are alternately long and short, set on a delicate homogeneous basement membrane.

Streptaxis deformis (fig. 6) has aculeate teeth, resembling those on the lateral portion of the dental membrane of *Zonites cellarius*. The young shell is like a *Zonites*; so that we may readily infer the close affinity of these genera.

The dental apparatus of *Cylindrella trinitaria* (fig. 12) is a singular modification of the inoperculate type. The band is very long, resembling in this respect that of *Littorina*. The individual teeth have a certain likeness to those of *Helix*, but they also recall to our minds, in their mode of arrangement, the Operculata.

The Inoperculata seem hardly to furnish us with much evidence as to their alliances with truly marine genera; but the operculate land-shells, on the contrary, exhibit unmistakeable affinities with several groups. As we have previously remarked, *Helicina* shows relations with *Nerita*: a comparison of them with *N. microstoma* (fig. 9) will prove the fact. A study of the lingual teeth has further made obvious what we might have expected from other characters, that the Cyclostomatidæ must be separated altogether from the Cyclophoridæ. The latter have teeth resembling those of *Littorina*. As examples we may cite *Cyclotus translucidus* (fig. 11) and *C. rugatus*. This dentition is represented by the formula 3 . 1 . 3. The animals of the Cyclostomatidæ, on the other hand, have a foot divided into two longitudinal portions by a groove. As examples of their dentition (00 . 2 . 1 . 2 . 00) figures are given of *Cistula pupi-*

formis (fig. 8) and *Adamsiella aripensis* (fig. 10). It would seem from this that the Cyclostomatidæ are probably not very closely related to the Littorinidæ. Their lingual teeth seem rather to point out an alliance with the Trochidæ, or one of the groups possessing *pleuræ*. But without attempting at present to decide this question, which can only be determined by the examination of several species, we may remark that the Cyclostomatidæ will probably be found a natural and defined group, perhaps entitled to the rank of a suborder, and not very closely related to any existing marine forms.

The relations of the freshwater Operculata are as varied as are those of the land. *Ampullaria* doubtless finds its nearest marine relative in *Natica*,—an opinion which seems confirmed by the form of the shell. The dentition of *Ampullaria urceus* and that of *A. effusa* (fig. 13) are very much alike, and *Marisa cornu-arietis* (fig. 14) does not differ very greatly; the mandible is also similar, showing that the claims of the latter to generic rank must be sought rather in the shape of the shell and the differences of the siphons than in the teeth. *Hydrobia spiralis* appears to be akin to the Melaniidæ; but we should not be surprised if it were found to be as close to *Skenea*.

The horny mandibles of the Mullusca may be deserving of some attention, with a view to the elucidation of their affinities. In *Cyclotus* (*translucidus*) the mandible (fig. 11*a*) is divided into two portions by a median articulation, and it is covered with fine acute denticulations in regular rows*. In most of the Inoperculata the mandible is horseshoe-shaped, and striate or corrugate. In *Ampullaria* the same organ is beak-shaped, like the upper mandible of *Octopus* or *Loligo*.

EXPLANATION OF PLATE XI.

Lingual Dentition of some West-Indian Gasteropoda.

Fig. 1. *Bulimus multifasciatus*, magnified 250 diameters. A wide band, $\frac{1}{8}$ of an inch in length, consisting of numerous rows of similar teeth; *medians* with a central toothlet, and a smaller point on each side; *laterals* in divergent rows, each with three toothlets, and an oblique, broadly reflexed cutting-edge. Mandible semicircular and corrugated.

Fig. 1*a*. Side view of central cusps.

Fig. 2. *Stenogyra octona*, magnified 300 diameters. A narrow band, $\frac{1}{20}$ of an inch in length; *medians* simple, minute, inconspicuous, central cusps longest; *laterals* tricuspid, with central cusp much prolonged. The ova of this species are subspherical, with a white testaceous envelope, sometimes remaining in the shell, whose aperture is thereby nearly filled up; they hatch after the death of the parent.

Fig. 3. *Marginella cærulescens*, magnified 300 diameters. A band $\frac{1}{4}$ of an inch long, of very pellucid, acute pyramidal teeth; *medians* shorter than laterals; *laterals* alternately a long and a short, set on the same plane; basement membrane homogeneous, very pellucid.

* Like *Aptychus*, but more horseshoe-shaped; it is more probable that these problematical fossils are the mandibles of Cephalopoda than the plates of their gizzards. They bear no resemblance in shape to the horny plates of the gizzard of a mollusk.

Fig. 4. *Plecocheilus auris-sciuri*, magnified 100 diameters. A broad ribbon, $\frac{1}{8}$ of an inch long, of subquadrate pellucid teeth; *medians* remarkable for the great length of their imbricated pellucid cusps; *laterals* having bases produced on both sides, and differing from medians in having similar central cusps, on each side of which is a nearly obsolete toothlet; the extreme outer rows modified in form as well as in character.

Fig. 4*a*. Side view of central cusps. Mandible semicircular, with coarse denticulations.

Fig. 5. *Tornatellina lamellata*, magnified 300 diameters. A narrow band, $\frac{1}{12}$ of an inch in length, of numerous pellucid teeth; *medians* small, simple, and inconspicuous, central cusps prolonged; *laterals* large and simple, with long pellucid acute central cusps, and two obsolete dentations on the outer side.

Fig. 5*a*. Side view of central cusps. The mandible is horseshoe-shaped, and composed of a number of pentagonal prisms laid obliquely, resembling the shell-structure of Brachiopoda. This species is viviparous, and during July and August is found full of young animals.

Fig. 6. *Streptaxis deformis*, magnified 150 diameters. Band $\frac{1}{8}$ of an inch long. Formula 10.1.10. *Medians* simple, aculeate; *laterals* subopaque, irregular, aculeate, enlarged at their insertion into the basement membrane. The animal is of a delicate pink or yellow colour; it is found both on trees and the ground in the forests.

Fig. 7. *Macroceramus signatus*, magnified 150 diameters. A narrow band, $\frac{1}{10}$ of an inch in length, filled with divergent rows of pellucid teeth; *medians* simple, elongated, with simple obtuse cusps; the *laterals* have two reflexed subequal cusps.

Fig. 7*a*. Side view of central cusps.

Fig. 8. *Cistula pupiformis*, magnified 300 diameters. 00.2.1.2.00. Lingual band small and delicate; *medians* denticulate, with acute cusps, outer cusps prolonged; 1*st laterals* broad at bases, with prolonged central cusps, and with subdued denticulations on either side; 2*nd laterals* broad, recurved, cusps well developed; *uncini* numerous and slender.

Fig. 9. *Neritina microstoma*, magnified 150 diameters. 00.3.1.3.00; *medians* subquadrate, narrowest towards their bases, subopaque; 1*st laterals* subtrapezoidal, with outer corner most produced; 2*nd laterals* prolonged, strongly curved outwards; 3*rd laterals* convex, broad, glassy, denticulate, with curved tips; *uncini* strong and numerous. Between the 2nd and 3rd laterals there appears to be a smaller or intermediate set of finer uncini; but whether they form a portion of the odontophore, and have become accidentally turned down, or really are another set, we have not been able to determine; the peculiarities, however, of the band appear to have been heretofore overlooked.

Fig. 10. *Adamsiella aripensis*, magnified 300 diameters. 00.2.1.2.00. A long slender band; *medians* denticulate, with acute cusps; inner *laterals* broad; outer denticulate on the reflexed edge; *uncini* numerous, slender, curved at their terminations: *a*, separated *uncini*; *b*, inner laterals; *c*, outer laterals, more highly magnified. The mollusk is frequently found suspended by two or three glutinous threads from under branches of low-growing shrubs.

Fig. 11. *Cyclotus translucidus*, magnified 150 diameters. 3.1.3. A narrow band $\frac{1}{2}$ an inch long; *medians* subquadrate, denticulate, cusps recurved, central ones large and acute; 1*st laterals* broad, more obtuse than the central, recurved, denticulate; 2*nd* & 3*rd laterals* simple, convex, or claw-shaped; bright amber-colour. The animal is of a pinkish colour, which is lighter about the body and foot, but deeper about the tentacles.

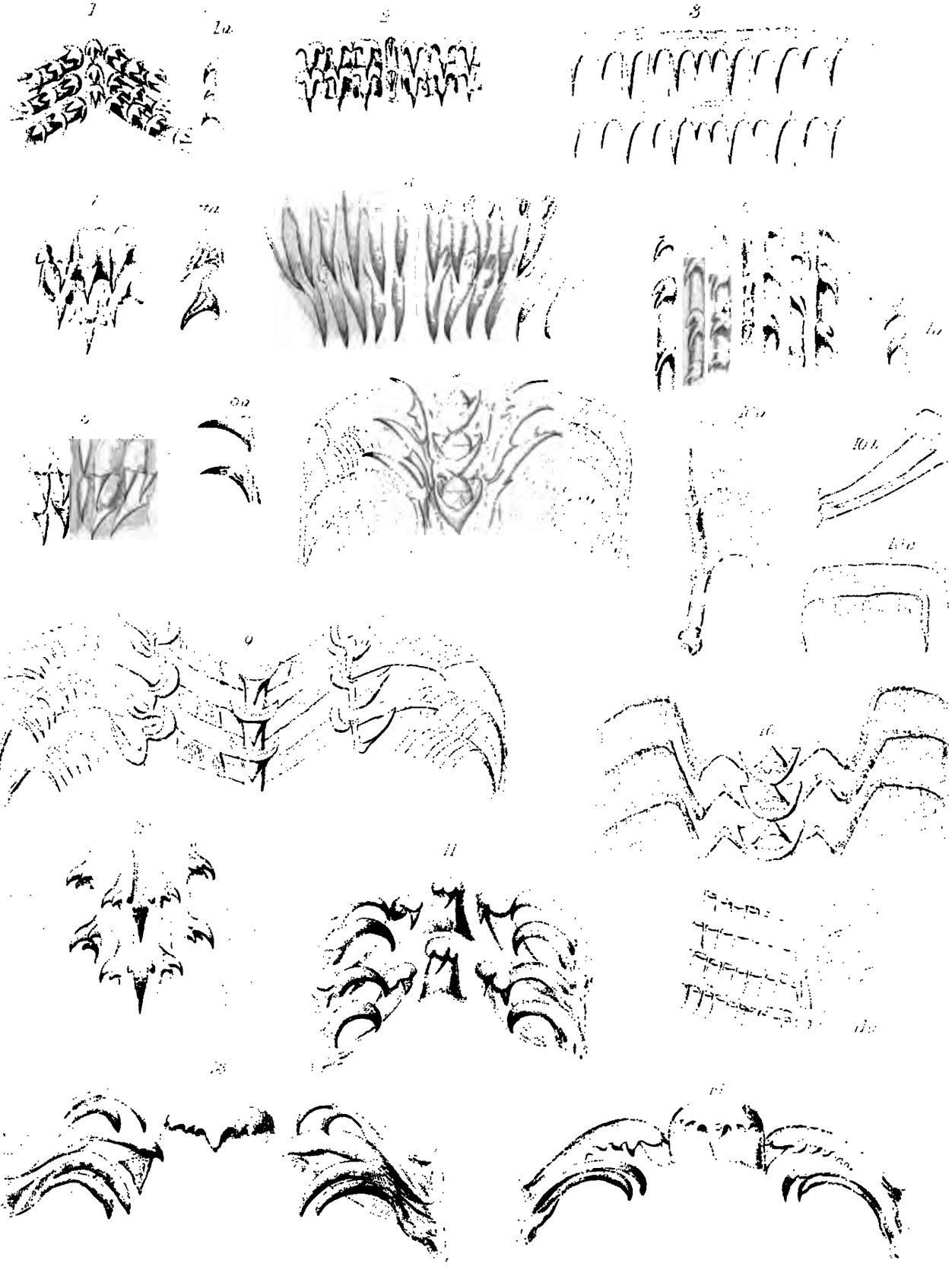
Fig. 11*a*. Mandible of *Cyclotus*, magnified 150 diameters. It is divided into two portions by a median articulation, and covered with fine acute denticulations in divergent rows.

Fig. 12. *Cylindrella trinitaria*, magnified 200 diameters. Formula 2.1.2. A narrow band $\frac{3}{10}$ of an inch in length; *medians* well developed, acute, tricuspid, tubercles on their bases; 1*st laterals*

with simple inconspicuous cusps; 2nd or outer more conspicuous, with recurved claw-shaped cusps.

Fig. 13. *Ampullaria effusa*, magnified 60 diameters. 3.1.3; *medians* broad, but smaller than those of *A. urceus*; central dentations strong, with three smaller obtuse ones on each side; 1*st laterals* with broad apical dentation on the inner edge, two less developed; 2*nd* & 3*rd laterals* smaller, and claw-shaped. Band $\frac{1}{10}$ of an inch long.

Fig. 14. *Marisa cornu-arietis*, magnified 60 diameters. 3.1.3. Band $\frac{1}{10}$ of an inch long; *medians* broad, with three dentations on each side of a strong acute central point; 1*st laterals* recurvate, claw-shaped, with three dentations on the inner side of a longer central tooth; 2*nd* & 3*rd* simple claw-shaped, with broad basis firmly set in basement membrane. Mandible very similar to that of *A. effusa*.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ON

THE AMOUNT OF

THE RADIATION OF HEAT, AT NIGHT,

FROM THE EARTH,

AND FROM

VARIOUS BODIES PLACED ON OR NEAR THE SURFACE OF THE EARTH.

BY

JAMES GLAISHER, Esq.,

Of the Royal Observatory at Greenwich.

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1847.

PHILOSOPHICAL TRANSACTIONS.

XI. *On the Amount of the Radiation of Heat, at night, from the Earth, and from various bodies placed on or near the surface of the Earth.* *By* JAMES GLAISHER, *Esq., of the Royal Observatory at Greenwich. Communicated by* G. B. AIRY, *Esq., F.R.S., Astronomer Royal, &c.*

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IN the Report of the Committee of Physics of this Society in the year 1840, the measure of the radiation of heat at night from the earth was specially mentioned as being of importance to meteorology; and it may be added that it is of the utmost importance to the economy of nature.

As soon as the duties of the Magnetical and Meteorological Observatory permitted, I employed some time in making myself acquainted with all that was known upon the subject of radiation. The results of my researches were only a few papers in the Transactions of this Society, and the Treatise on Dew by Dr. WELLS; and in general I found a great want of good observations; I therefore determined to pursue the subject with some degree of steadiness. The instrument recommended to be used in the report above referred to, was a self-registering minimum thermometer, placed in the focus of a polished metallic reflector; and, in consequence of this recommendation, the instrument has been in very general use; it was, however, mentioned as being an imperfect instrument.

The instrument being thus confessedly imperfect, it became exceedingly desirable to ascertain the amount of its errors; and, to this end, to have very many comparisons made between it and those instruments or methods which might be found less imperfect, so as to have a ready and certain means of converting the results derived from observations by it to other results, if it were found desirable so to do. With this view the thermometer, whose bulb was placed in the focus of a reflector, has been read, almost without exception, in every series of experiments.

My first object was the obtaining instruments of the best possible kind, and I con-

sidered that the essentials of the thermometers adapted to the investigation were threefold, viz.—

1st. That the points corresponding to the freezing and boiling of water be exactly determined.

2nd. That the column of mercury which fills the tube be exactly uniform throughout.

3rd. As bodies exposed to the sky must radiate as much heat to it during the prevalence of wind as they would do if the air were still, and as I had always found, during the continuance of the strongest and most steady winds, that there were periods of calms of some duration, it was necessary that the thermometers should be of the most delicate kind, and the most sensitive to the variations of heat, so that they would mark a superficial or transitory cold, as, if not, the frequent application of warm air in windy weather would quickly return a heat equal to that lost by radiation.

With the view of obtaining instruments combining these essentials, I placed myself in correspondence with Mr. Watkins, optician, in the year 1842, described to him the kind of instrument I wanted, and the purpose for which I required them, and after this time I frequently received different thermometers from him for the purpose of experiment. I was thus occupied during many months in making these experiments upon thermometers whose stems were varied in their lengths, some embracing an extent of upwards of 212°; others of a less extent, but whose lengths for a degree were different; to some of these divided scales were applied, varied in their kind and form, hinges being furnished to several, so that a part of the stem and the bulb were free; and others were without any scales affixed to them whatever, the divisions being cut on their own stems; other experiments were made upon thermometers whose bulbs were varied with respect to their form, size and colour; and in general, the results of the experiments tended to the obtaining of instruments which would give the most accurate results.

The following are some of the results of these experiments:—

Being desirous of testing the points 32° and 212° myself, so that I could determine their errors, as also the errors of the other parts of the scale by means of Bessel's formula (Konigsberg Astronomical Observations for 1821, p. 9)*, I was anxious for instruments whose extent of division should embrace these points; I soon, however, abandoned this idea, as it would have required thermometers with very long stems, a circumstance I found materially to affect their readings, which varied with every different inclination of the thermometer to the horizon, and were correct only when placed horizontally. I did this the more readily as I was in possession of an instrument which had been made for me by Messrs. Watkins and Hill ten years previously, the point corresponding to 32° of which had been examined every year, and found to be correct; the readings of this instrument had also been compared with the best standard instruments we possess, and found to agree with them at every part

* See a full illustration of this method in Kupffer, Annuaire Magnétique et Météorologique for the year 1841, pp. 41 to 51.

of the scale; I therefore determined to use this as a standard with which to compare every thermometer.

I also found that it was absolutely necessary to have the division marked on the thermometer stems themselves; for those to which scales were affixed, even those furnished with hinges, so that a part of the stem and the bulb were free, and those whose bulbs projected beyond the scale could not be laid so nicely on different substances as those without scales; for that and other reasons all the thermometers used in the following experiments were without scales affixed to them, the divisions being engraved and coloured upon the stems themselves.

In the course of the experiments I found that circular bulbs were the more sensible in proportion to their smallness, but with a bulb sufficiently small to have the desired sensibility, the column of mercury was so fine that it would have been impossible to observe accurately with it at night in the position in which the instruments were necessarily placed in these observations.

The length of the thermometer finally used was thirteen inches, including the bulb, whose diameter was a quarter of an inch, and length three quarters of an inch (as shown in the figure); therefore, as the instruments were divided from 0° to 130°, each degree was about 0·1 inch in length; these were used during the night observations, and they were left on their respective substances till about 9 o'clock in the morning, until it was found that many of them were broken; the absorptive power of grass and the filamentous substances being such that before this time a temperature of more than 130° had taken place even in the month of April; other instruments were afterwards constructed both of the same length and of the same form, and graduated as far as 160° or 170°. These were occasionally used during the night observations, and always during those of the day in experiments upon the absorptive powers of different substances.

These instruments were so delicate that on taking them from air of the temperature of 60° to that of 37°, the latter temperature was indicated in about two minutes; and therefore if at any time a lull took place in a gale of wind of two minutes' duration, or even less, the amount of heat lost by radiation under the then state of the sky would be correctly registered by these instruments.

On September 13, 1843, I received twenty-five mercurial thermometers of the above form, and as many self-registering minimum thermometers, with circular bulbs, whose divisions were also on their own glass stems; and at this time I commenced the regular series of observations with the mercurial thermometers; that with the minimum thermometers had been begun long before. A year was consumed in these preliminary experiments, and in ascertaining the precautions necessary to obtain correct determinations; in consequence of several of these being neglected before this time, the previous observations must be regarded as undeserving of confidence; the results from them therefore have been omitted in the following Tables.

I now proceed to speak of the comparison of the thermometers with the

standard. Among others received in January 1843, were five of the form finally adopted for use, and the following are the comparisons with the standard, made by hanging them in the air and near to the latter :—

1843. Month, day, and hour.	Reading of standard thermometer.	Reading of thermometers.				
		a.	*b.*	*c.*	*d.*	*e.*
d. h.	°	°	°	°	°	°
Feb. 5 22	34·8	34·8	34·8	34·8	34·8	34·7
6 0	35·7	35·4	35·6	35·6	35·6	35·7
6 1	36·4	36·2	36·3	36·2	36·3	36·3
13 22	35·9	35·8	36·0	35·8	35·9	35·9
13 22½	36·4	35·9	36·0	36·1	36·2	36·3
13 23	37·0	36·8	37·0	37·0	37·0	37·4
14 1	39·0	38·8	39·0	39·2	39·2	39·2

The following comparisons were made of those received on September 13th by means of water of different temperatures in the following manner. Water of a higher temperature than needed was placed in a vessel, and the required temperature was obtained by the application of cold water, the two being well mixed together till the standard thermometer read the same at every part of the mixture. The thermometers were then all placed in it and parallel to each other ; they were thus allowed to remain for one hour, and their readings were taken quickly. Water of a different temperature was then prepared in a similar way, and so on successively. The comparisons occupied an entire night, and during this interval of time the temperature of the room was kept uniform, in fact it did not vary one degree.

This method was found to be very troublesome, and to ensure accuracy a long time was required to be devoted to it. The mixing of water of different temperatures together, so that the whole mixture became of the same temperature, from the circumstance of its being so bad a conductor of heat, was found to be difficult. After this time I adopted the following method in all subsequent comparisons :—

1st. The water was heated to a temperature above the highest required.

2nd. The standard and all the thermometers for comparison were placed, in this water, parallel to each other, and after some time their readings were taken as quickly as possible.

3rd. The readings were afterwards taken as the temperature of the water declined every 2° or 3°, till the temperature of the water was at or near that of the apartment ; in case the decline of temperature was found to be too rapid, the surface of the water was covered by flannel.

4th. A quantity of water was cooled to a point lower than the lowest required temperature, by means of ice, or of ice and salt, and the thermometers were placed in this as before.

5th. The readings of all the thermometers were taken as this mixture increased 2° or 3° in temperature, till it was at or near the temperature of the apartment, its surface being covered by flannel if the increase of heat was thought to be too rapid.

By this means the comparisons were made with ease and certainty, and they readily indicated every inequality of the thermometer tubes.

1843.	Greenwich mean time Oct. 21d.				Correction to be added to readings of the thermometers.
Name or letter of reference of the thermometer.	7h 30m.	11h 30m.	15h 30m.	17h 40m	
Standard.	45°·1	49°·8	69°·3	90°·5	
A.	45·1	49·8	69·3	90·5	
B.	45·1	49·8	69·3	90·5	
C.	45·1	49·8	69·2	90·5	
D.	45·0	49·8	69·3	90·4	
E.	45·1	49·8	69·3	90·3	
F.	45·1	49·8	69·3	90·4	
G.	45·0	49·8	69·3	90·4	
H.	45·1	49·9	69·3	90·5	
I.	45·1	49·8	69·2	90·4	
J.	45·0	49·7	69·3	90·4	
K.	45·0	49·7	69·3	90·4	
L.	45·0	49·8	69·3	90·4	
M.	45·0	49·8	69·3	90·4	
N.	45·1	49·8	69·3	90·5	
O.	45·1	49·9	69·4	90·5	
P.	44·6	49·4	69·0	90·0	Add 0°·5 to all readings.
Q.	44·9	49·6	69·2	90·3	Add 0°·2 to all readings.
R.	45·0	49·8	69·3	90·5	
S.	44·8	49·5	69·0	90·2	Add 0°·3 to all readings.
T.	44·8	49·5	69·0	90·2	Add 0°·3 to all readings.
U.	45·1	49·8	69·2	90·5	
V.	45·1	49·6	69·2	90·5	
W.	45·1	49·7	69·1	90·5	
X.	45·1	49·8	69·1	90·5	
Y.	45·1	49·6	69·0	90·4	

During the operation of comparing the thermometers, it was found absolutely necessary to have all of them in the same position with respect to the vertical, for it sometimes happened that their readings varied with their position; this variation with the self-registering minimum thermometers was so great that I could not compare them at this time; afterwards I procured a shallow vessel of sufficient extent to receive them horizontally; in this vessel the comparisons were taken, and their readings were found to agree with those of the standard to 0°·1 or 0°·2, the same thermometer being frequently as much in excess at one part of the stem, and as much in defect at another.

The possession of upwards of fifty instruments whose extreme difference of reading from the standard was a constant quantity of half a degree in one thermometer, and a constant quantity of 0°·2 or of 0°·3 in three others, the remainder being absolutely free from error, was exceedingly gratifying. I felt that all the time and trouble I had bestowed on them was well repaid. I had not expected to be so successful in obtaining so many essentially good thermometers, and I had prepared myself to ascertain their errors at every division by Bessel's formula, which, although implying a long process, gives good results; all this trouble, however, I was saved, and also

all the work which would have been necessary in applying the correction, had such been needed.

The construction of such instruments must be considered as highly creditable to Messrs. WATKINS and HILL, and I feel that I should be doing an injustice to Mr. WATKINS, did I not here mention my obligations to him for his readiness at all times to meet my wishes, which I fear were sometimes troublesome.

The observations were made in the grounds attached to the Royal Observatory, being S.S.E. of the Magnetic Observatory, and distant from it about forty feet.

The form of the piece of ground is nearly square; its extent about 10,000 square feet, and its surface nearly level. At one end is the extreme south arm of the Magnetic Observatory, whose height is twelve feet and breadth thirteen feet; at fourteen feet north of this arm, the two east and west arms project each fourteen feet, and their height is the same as the south arm. On each of the three remaining sides, at the distance of about forty-five feet, is a close wooden fence, between five feet and six feet high. At the distance of ninety feet north-west is a fine and spreading oak-tree, and a little beyond it are other trees but of a less elevation. On the east and near the outside of the fence are chestnut-trees. All these circumstances had influence on the readings, and caused them to be higher (particularly those that were made on or near the surface of the ground), and therefore the differences of the readings, as compared with those in the air, were less than they would have been if the surrounding fence and trees had been further removed, or the observations had been made in a wide and open plain, and I have reason to believe to a much greater extent than would at first appear to be the case.

A portion of the grass plat containing 210 square feet, whose nearest part was twenty-eight feet south of the Magnetic Observatory, was enclosed by low and open palings; within this enclosure the self-registering minimum thermometers were placed after April 1843, and some of them continued to be regularly observed till the present time (1847). At one angle of this enclosure a piece of board six feet long, four feet wide, and 1¼ inch thick, was elevated three feet above the grass plat, by means of four props of equal height; upon this raised board all experiments upon substances in the shape of powder were made.

I now proceed to speak of some of the substances upon which experiments have been made. Those on the temperature of grass were always made both on long and on short grass, the blades of the former being bent by strong pressure towards the earth, and overlapping each other so as to completely cover the surface of the ground; the blades of the latter, being less than an inch in height, were erect and stiff; in this respect only did the latter differ from the former, each portion being a part of the same grass plat, separated from each other by a few feet only, and therefore exposed to the same portions of the sky. The metallic plates used had generally a surface of more than 100 square inches. The thermometers for ascertaining the temperature of the air at distances from one inch to twelve feet from the earth, were placed with

their stems passing through a piece of wood planted firmly in the ground, and whose thickness was two inches and breadth three inches, with the bulbs at least nine inches from the wood.

Bodies in the state of powder were generally in quantity such that about thirty square inches of surface were exposed, and their thickness was about half an inch. The filamentous substances exposed a surface of about 100 square inches, and their thickness was about half an inch. With respect to the other substances, the circumstances under which the observations have been made are sufficiently explained in the section of observations. The thermometer was laid on long grass in such a manner that the bulb was not covered by a single blade; on short grass it rested on the fork of two Y's, so that the bulb was sustained on the top of the grass; on metallic plates it was so laid that the bulb occupied the centre of the plate; on substances in powder it was so placed that the bulb occupied the centre of the mass, and just in contact with it, the stem being supported by pieces of wood; on filamentous substances the bulb occupied the centre, and care was taken that it did not sink within, or was covered by any portion of the substance; and the same plan was adopted throughout all the experiments.

During a series of observations the thermometers were frequently removed from one substance to another; those whose readings were the highest were interchanged with those which were the lowest, and so on: in the case of observations of the same kind of metals at different heights, or of different thicknesses, or indeed in any specific comparison, they were always interchanged among themselves; it is possible that had the same instrument remained on the same substance, or in the same position, a more even set of readings in some cases might have been made: but this interchange of instruments removed all doubt as to the cause of the differences in the readings being altogether due to the difference of position, or to the inherent quality of the body itself upon which the instrument was placed. Some of the other precautions used in taking the observations were as follows. First, the observer approached the instrument at that end which was the most distant from the bulb, and held his breath during the time; and the readings were taken as quickly as possible, so that no heat should be imparted to them from the observer's body. In consequence of their divisions being cut on glass, a difficulty was at first experienced in reading them without placing the reading-lamp too near to the instruments: habit after some time enabled the observer to place the lamp so that the divisions were instantly perceived. Another and a greater difficulty was that of readily seeing the top of the mercury, in consequence of the fineness of its column: after various experiments it was found that this became readily seen by slipping a piece of coloured card under the instrument at about the place where it was known the column terminated: the colours found to answer best were drab and yellow. I may mention here that attention was paid to every precaution that experience suggested, or reflection pointed out as desirable.

Each set of observations may be looked upon as a series of experiments made for the purpose of ascertaining the different tendencies of various bodies to become cold upon exposure to a cloudless sky at night. To many persons it must be a new fact, that a perfectly dry body, placed in contact on all sides with other bodies of the same temperature with itself when the sky is covered by clouds, shall on the sky becoming less cloudy or cloudless, become much colder than those bodies, to so great an amount as is exhibited in the following tables, and that it shall remain so for many hours; yet these circumstances were exhibited in every series of observations*.

The formation of dew was found to depend solely on the temperature of the bodies upon which it was deposited, and it never appeared upon them till their temperatures had descended below that of the dew-point in their locality, as found by observations of a dry and wet bulb thermometer placed in their vicinity.

The amount of water thus deposited was the greatest upon the substances whose temperatures were the lowest: among these bodies glass was found to radiate heat freely, and it very readily became wet with dew. In consequence of this property, the tube of a naked thermometer, which was lying on a substance entirely free from moisture, was frequently found covered by dew, and therefore it seemed probable that the temperature exhibited by the instrument was not that of the body in question. On such instances occurring an attempt was made to correct the error by enclosing the thermometer stem in a tube made of gilt paper; the bulb alone, resting on the substance, remained exposed to the sky. The differences between the readings of a thermometer thus enclosed, and when naked, were found to be sensible, but small in amount; it was observed that when the thermometer was wholly naked, the stem was at times wet when the bulb itself was dry; and at all times much less moisture appeared on the bulb than on the stem, unless the disposition of the substance in question to become cold was the same, or greater than that of glass. The error arising from this cause was chiefly confined to the consequent contraction of the mercury in the stem, and not in the bulb, and which was considered to be avoided by the use of gilt paper: the error in all cases must have been small. It was found that the differences between the temperature of the air and of bodies on the earth, at night, in equally calm and clear weather, was the same at every period of the year, but it was found that the amount of dew deposited during such times was much greater in summer than in winter. This is easily accounted for, from the now well-known relation existing between temperature and moisture. At all seasons of the year, at night, the depression of the temperature of the dew-point below that of the air is small, or the air is in a state of saturation nearly, and therefore in summer a certain diminution of temperature would cause much more vapour to be changed into water, than an equal diminution in winter would do.

Radiation of heat from the earth to the heavens must exist at all times both day and night, and in all states of the sky. Generally, when the sun is above the

* The whole of these observations are placed in the Archives of the Royal Society.

horizon, the heat emitted by it to the earth will overbalance that which the earth radiates upwards; at times however, in places shaded from its direct beams, the amount of heat radiated exceeds that received from the sun and all other sources, and dew will be continually deposited throughout the day. Some instances of this are exhibited in the following Tables.

In taking these observations I have been much assisted by my then colleagues in the Magnetical and Meteorological Department of the Royal Observatory, viz. Messrs. DUNKIN, HIND and PAUL: these gentlemen frequently, on my commencing a series of observations, continued them as long as circumstances required, or they have begun a series which were continued by myself; and whenever any doubt attached to the readings from the unexpected lowness of the thermometers or other causes, they were always confirmed by one or other of these gentlemen, and afterwards by an interchange of instruments.

I have also to acknowledge my obligations to the Astronomer Royal for his kindness in permitting me to carry on these experiments within the grounds of the Royal Observatory; also for providing me with a skeleton form in which the observations were registered; and also for inclosing the piece of ground within which the registering instruments were placed.

The whole of the calculations have been twice performed by myself at different times, and parts of them, which appeared to be more liable to error than others, have been examined by another person. I believe, therefore, the whole to be nearly correct.

SECTION I.—*Results of Simultaneous Observations made by Mercurial Thermometers, not self-registering.*

The first process in the reduction of these observations, was to take the difference between the reading of the thermometer, freely suspended in air, at the height of four feet, and protected from the effects of radiation, and the simultaneous reading of every other thermometer.

The next process was to divide these differences into groups, arranged according to the excess of the reading of the thermometer, suspended in the air, above that placed on long grass.

The next step was to collect all these differences under the head of their respective substances for every degree of such excess of air temperature above that of long grass temperature.

The next step was to arrange these numbers according to the dates of their occurrence, and to write out abbreviative remarks which were made at the time of observation; and in this way the following Tables have been formed.

Tables I. to XVI. contain the results deduced from the observations taken between 1843, September 13, and 1843, November 15; Tables XVII. to XXVIII. contain the results from the observations taken between 1843, November 16, and December 31; and Tables XXIX. to XLIV. contain those from observations taken between 1844, January 1, and 1844, May, 1.

Excess of the reading of a thermometer placed in air at the height of 4 feet, protected from the effects of radiation, above the readings of thermometers placed on different substances fully exposed to the

Number of the Tables.	1813. Astronomical day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed: On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On garden mould.	On gravel.	On river sand.	On river sand on the raised board.	One inch high above grass.	Two inches high above grass.	Three inches high above grass.	Six inches high above grass.	Twelve inches high above grass.	On unwrought white cotton wool on grass.	On unwrought white cotton wool on raised board.	On raw wool on raised board.	On flax on raised board.
	h m	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
I.	Sept. 13. 19 20	54·8	−2·2	−2·2	...	...	...	...	...	...	...	...	0·0	−2·2	−2·2	−2·2	0·8	.....	...	...	−2·2	−2·2	...	...
	17. 19 20	61·5	−0·7	−0·2	...	...	−1·0	...	...	...	...	−1·0	0·0	−0·5	−1·3	−1·2	...	1·7	...	...	...	...	...	...
	22. 18 0	52·2	−1·1	−0·8	...	...	0·0	...	...	...	...	...	...	−1·4	...	0·4	...	0·4	...	..	−2·3	...	...	...
	22. 19 20	54·2	−2·3	−1·1	...	...	−0·8	...	...	...	...	...	...	−1·8	...	0·2	...	0·9	...	...	−3·8	...	...	...
II.	24. 18 40	49·0	0·2	0·9	...	...	2·0	1·0	...	...	...	...	...	0·0	...	1·0	...	1·7	...	...	−0·8	...	...	...
	26. 19 20	44·5	0·8	1·3	...	...	0·5	...	...	...	...	...	...	−1·7	...	0·5	...	1·3	...	...	−2·7	...	...	...
	Oct. 15. 19 20	32·0	0·4	1·7	2·4	2·2	−0·1	1·3	...	...	...	...	...	...	...	1·7	...	...	1·2	...	2·2	...	...	...
III.	Sept. 24. 18 15	48·7	1·3	1·6	...	...	2·6	1·6	...	...	...	−0·1	...	...	...	1·7	...	1·8	...	...	0·4	...	...	...
	26. 17 35	40·8	1·7	1·4	...	...	2·4	...	...	...	...	...	...	0·3	...	1·2	...	1·6	...	...	1·0	...	...	...
	Oct. 16. 14 50	40·0	1·0	1·0	1·0	1·0	2·0	0·5	...	...	...	...	...	...	...	1·0	...	1·0	...	...	1·0	...	...	...
IV.	Sept. 18. 17 30	60·3	2·5	2·1	...	...	...	...	...	...	...	1·3	2·5	2·3	...	2·3	...	1·7	...	...	2·0	...	...	...
	Oct. 3. 11 35	58·3	2·6	2·3	...	...	1·7	0·4	...	...	...	1·8	...	...	...	1·6	...	...	0·7	...	2·5	...	...	...
	4. 11 20	55·7	2·7	2·7	...	...	1·9	1·7	...	...	...	...	...	2·7	...	2·7	...	...	2·7	...	2·5	...	...	...
	12. 18 25	38·5	2·5	2·5	2·0	2·5	2·5	2·5	...	...	...	...	...	...	...	2·5	...	...	2·0	...	2·5	...	...	...
V.	Sept. 20. 18 20	50·7	3·7	3·0	...	...	2·5	...	...	...	...	1·5	...	...	...	1·9	...	2·1	...	...	4·7	...	...	...
	21. 13 20	57·2	3·2	3·0	2·9	...	0·7	...	...	...	...	...	...	2·6	...	2·1	...	0·6	...	...	...	...	...	...
	22. 15 30	50·5	3·3	2·9	1·3	...	2·9	1·1	...	...	...	...	...	2·3	...	3·3	...	1·2	...	...	...	...	...	...
	Oct. 12. 17 15	38·0	3·2	3·2	5·0	5·0	3·0	2·0	...	...	...	...	...	...	...	3·0	...	...	2·0	...	5·0	...	...	...
	13. 15 20	41·5	3·5	3·0	3·0	2·2	2·7	0·9	...	...	...	...	...	...	...	1·9	...	...	1·2	...	3·0	...	...	...
	18. 21 0	38·2	3·0	3·0	5·5	4·0	4·5	...	...	...	...	2·7	2·8	0·8	...	3·0	...	...	1·0	0·8	...	3·5	...	...
	27. 5 0	44·0	3·3	1·8	2·2	2·9	2·0	1·0	−3·0	−1·5	...	0·8	−0·7	0·4	...	2·0	...	...	1·0	0·9	2·7	...	...	...
	Nov. 3. 7 40	48·1	3·1	3·8	6·7	6·1	3·9	1·1	−0·5	−2·1	...	1·9	2·1	3·3	...	3·1	...	...	0·5	−0·1	5·0	...	...	...
	4. 7 0	42·5	3·8	2·0	7·0	6·3	2·7	1·5	−5·5	−1·0	...	−0·5	−2·5	−0·6	...	1·5	...	...	0·7	0·2	3·0	...	...	...
	9. 6 30	32·5	3·5	2·7	2·0	2·0	2·5	0·9	−6·0	−2·3	...	0·5	0·7	0·5	...	...	...	...	−0·3	−0·2	3·5	...	...	...
VI.	Sept. 13. 15 37	49·5	4·5	4·5	...	...	6·5	...	...	...	...	...	0·5	4·5	4·0	4·5	3·0	...	...	...	4·5	4·5	...	...
	21. 9 10	60·7	4·7	4·7	...	...	3·9	...	...	...	...	...	...	4·3	...	4·3	...	2·4	...	...	4·5	...	...	...
	Oct. 3. 15 20	55·6	4·9	4·0	...	...	3·6	2·4	...	...	...	3·2	...	...	...	3·3	...	...	2·4	...	7·3	...	...	...
	5. 11 0	54·5	4·5	4·1	...	...	3·5	2·0	...	...	...	3·3	...	...	...	3·3	...	...	2·5	...	...	...	...	...
	13. 11 0	41·5	4·8	4·5	4·7	3·5	4·3	2·0	...	...	...	...	...	...	...	3·5	...	...	1·5	...	4·5	...	...	...
	13. 20 40	40·5	4·5	3·5	8·5	4·5	2·5	...	...	...	...	...	...	...	...	2·5	...	...	1·5	...	8·5	...	...	...
	20. 11 20	42·3	4·8	3·8	5·8	5·5	3·8	0·8	−0·7	0·3	...	1·5	1·8	1·5	...	2·3	...	...	0·1	0·1	5·1	...	...	...
	20. 13 0	44·8	4·0	1·8	3·6	4·0	1·8	0·0	−1·3	1·3	...	0·8	1·0	0·8	...	1·6	...	...	−0·2	−0·2	2·6	...	...	...
	23. 7 30	49·2	4·3	3·0	5·2	5·0	3·6	0·7	0·0	0·5	...	1·2	1·1	2·0	...	2·4	...	...	0·0	−0·6	4·2	...	...	...
	Nov. 3. 10 30	52·1	4·1	2·3	4·6	6·1	3·6	0·6	−3·3	4·0	...	2·9	3·6	3·3	...	3·9	...	...	0·6	0·1	4·6	...	...	...
	7. 9 0	43·1	4·1	5·9	9·1	7·9	5·3	2·3	−3·0	1·9	...	2·3	2·1	1·6	...	3·5	...	...	0·3	0·1	6·1	...	...	...
	15. 5 10	37·0	4·0	4·0	4·4	4·0	4·2	1·8	−3·0	...	...	...	...	...	...	...	...	...	1·0	0·2	4·0	...	...	...
VII.	Sept. 13. 15 24	50·0	5·5	6·0	...	...	8·0	...	...	...	...	...	1·0	6·0	5·0	6·0	3·5	...	...	...	6·0	5·5	...	...
	13. 17 20	51·5	5·5	5·5	...	...	...	...	...	...	...	...	1·0	5·5	4·5	5·5	3·5	...	...	...	5·5	5·5	...	...
	17. 17 20	58·0	5·2	3·0	...	...	...	...	...	...	...	2·8	1·2	2·9	2·6	2·3	...	1·8	...	...	...	...	...	...
	20. 16 20	51·0	5·0	3·8	...	...	3·0	...	...	...	...	...	3·8	...	...	4·0	...	2·0	...	...	6·7	...	...	...
	20. 17 20	50·0	5·8	3·8	...	...	2·2	...	...	...	...	...	3·0	...	...	3·0	...	2·6	...	...	6·9	...	...	...
	Oct. 2. 9 20	57·2	5·9	4·7	...	...	3·6	1·2	...	...	...	...	...	3·6	...	3·4	...	...	1·8	...	5·2	...	...	...
	3. 11 10	58·3	5·8	5·7	...	...	3·5	2·3	...	...	...	2·7	...	...	...	2·8	...	...	1·9	...	6·3	...	...	...
	5. 9 30	53·5	5·2	4·5	...	...	3·5	2·0	...	...	...	.....	...	3·2	...	3·5	...	...	2·5	...	...	...	...	...
	9. 18 0	39·2	5·2	3·8	...	...	2·7	2·4	...	...	...	−0·8	...	2·7	...	2·2	...	...	2·2	..	...	...	...	...
	12. 15 15	35·7	5·7	5·9	10·0	7·0	5·9	3·2	...	...	...	...	...	...	...	3·9	...	...	3·2	...	8·2	...	...	...
	16. 13 0	36·5	5·5	3·5	4·5	4·5	5·5	1·0	...	...	...	...	...	...	...	3·5	...	...	2·5	...	4·5	...	...	...
	23. 5 15	50·5	5·3	4·7	14·4	9·0	5·5	2·0	−0·4	1·0	...	2·3	2·0	3·5	...	3·3	...	...	1·0	0·3	12·7	...	...	...

Oct. 16, $14^h\ 50^m$; rain falling. Sept. 18, $17^h\ 30^m$; after a heavy rain. Sept. 20, $18^h\ 20^m$; after the sun had risen, clouds thin in zenith. Oct. 12, $17^h\ 15^m$; rain. Oct. 18, $21^h\ 0^m$; sun high. Oct. 3, $15^h\ 20^m$; the stars are shining dimly. Oct. 5, $11^h\ 0^m$; a few stars have been visible occasionally east of zenith. Oct. 13, $20^h\ 40^m$; the sun had risen more than two hours. Nov. 3, $10^h\ 30^m$; nocturnal rising temperature of the air, and the reading of the barometer is decreasing. Sept. 17, $17^h\ 20^m$; deposition of moisture. Oct. 9, $18^h\ 0^m$; clouds in every direction. Oct. 12, $15^h\ 15^m$; some rain had fallen.

Oct. 18, $21^h\ 0^m$. The observations at this time have not been used in subsequent calculations, they were taken after a long series of observations, extending over the whole night. On examining the state of the different substances at this time, it was found that every fibre of cotton wool was encrusted with a beautiful fringe of hoar-frost, and there were a few spikes of ice: raw wool was covered with lumps of ice, and there were some clear transparent flakes of ice, resembling

sky, arranged according to the difference of the readings of the one on Long Grass and that in Air, from observations taken between 1843 Sept. 13 and Nov. 15.

Excess of the reading of the thermometer in air above that placed																							Clouds.		Wind.		
On course flax on grass.	On yellow cotton wool on grass.	On yellow cotton wool on raised board.	On blue cotton wool on grass.	On blue cotton wool on raised board.	On white wadding on grass.	On black wadding on grass.	On flannel on grass.	On flannel on raised board.	On raw silk on grass.	On raw silk on raised board.	On silk from cocoon.	On the raised board.	On saw-dust on the raised board.	On black-lead on raised board.	On charcoal on raised board.	On lamp-black on raised board.	On whiting on raised board.	On chalk on raised board.	On tinfoil.	On lead.	On pantile.	On slate.	One-fourth of an inch above water.	On paper on raised board.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	−0·9	−0·9	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	−1·3	−3·0	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	0·9	0·7	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	−0·9	−1·3	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
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2·2	2·8	...	3·0	...	...	...	...	...	2·5	...	3·0	2·5	3·2	3·0	3·0	...	3·8	...	...	...	...	...	...	...	Clear	...				
1·8	...	1·3	...	0·4	...	...	...	1·5	...	1·0	...	...	1·4	1·4	1·2	...	1·8	...	...	...	...	...	1·0	...	Cirrostratus	10				
7·2	...	3·4	...	3·1	...	...	...	3·0	3·1	...	...	1·1	...	3·1	2·6	...	2·8	3·8	...	...	0·5	1·5	1·9	...	Cirrostratus	10	H.			
5·3	...	1·0	...	0·5	...	...	4·3	...	3·0	...	...	...	...	1·5	0·5	...	0·3	0·5	−0·3	1·0	0·5	0·5	−0·5	...	Cirrostratus	10	H.			
2·5	1·5	...	1·5	...	1·3	...	1·5	...	2·0	...	...	...	...	−0·3	1·0	...	...	...	...	...	...	...	0·2	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·5	3·3	...	...	...	...	...	...	...	...	...	Cirrostratus	10	H.			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·6	...	...	...	...	...	...	...	...	...	Cirrostratus	10	H.			
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5·3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	8	H.			
3·8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10	H.			
4·5	...	2·6	...	3·0	...	...	...	2·4	...	...	...	...	...	2·9	2·3	...	3·6	...	...	...	...	...	1·6	...	Cirrostratus	10				
6·1	...	4·1	...	4·1	...	...	...	4·1	4·1	...	...	2·1	...	...	...	...	...	2·6	...	...	...	...	3·1	...	Cirrostratus	10	H.			
8·1	5·1	...	3·1	...	...	...	4·0	...	3·9	...	...	...	...	...	...	...	...	...	...	2·7	2·0	2·0	...	...	Clear, nearly	1	...	s.	2	
4·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
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7·5	5·5	...	6·3	...	...	...	5·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear					

mica when abundant in granite; every fibre of flax was encrusted with ice, mixed with a few small flakes: raw silk was covered with spikes one-sixteenth of an inch in length, two of which emanated from the same point, and whose angle of separation was 30°: on blue and yellow wool there were many perpendicular spikes one-fourth of an inch in length: flannel was covered with spikes one-eighth of an inch in length, all of which were inclined to the horizon at an angle of 60°: saw-dust was very beautifully covered with spiculæ fans, formed by several spikes emanating from the same point at all angles greater than 30° with the horizon; these spikes were connected with each other by lateral spikes or bands; the whole forming the appearance of a fan, whose extent was 120°.

Sept. 23, 5ʰ 15ᵐ. The observations taken at this time have been inadvertently omitted in subsequent calculations.

In the column whose heading is "Direction of Wind," N. denotes north; E. east; S. south; W. west; C. calm, and G. gusts.

TABLE (Continued).

Number of the Tables.	1843. Astronomical day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed																					
			On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On garden mould.	On gravel.	On river sand.	On river sand on the raised board.	One inch high above grass.	Two inches high above grass.	Three inches high above grass.	Six inches high above grass.	Twelve inches high above grass.	On unwrought white cotton wool on grass.	On unwrought white cotton wool on raised board.	On raw wool on raised board.	On flax on raised board.
	h m	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
VII. (Continued.)	Oct. 25. 21 0	34·1	5·1	4·1	6·1	6·1	4·1	2·1	−7·9	−5·4	...	6·1	4·1	2·1	...	3·1	...	...	1·9	1·9	6·1	2·6	...	...
	26. 17 30	33·1	5·8	2·6	5·4	5·4	4·5	1·2	−7·7	−5·0	...	2·4	3·2	2·0	...	2·3	...	...	1·1	0·0	5·6	...	...	...
	Nov. 3. 5 30	49·3	5·3	5·3	7·5	8·1	6·3	2·0	...	...	...	...	1·5	2·5	...	3·7	...	...	1·4	0·7	7·1	...	...	...
	7. 10 0	42·5	5·0	5·3	8·5	6·5	5·7	2·2	−4·5	0·0	...	3·0	2·7	3·0	...	4·5	...	...	0·3	−0·2	7·0	...	...	5·5
	7. 11 10	43·5	5·5	6·3	9·5	6·5	6·5	2·1	−1·7	2·5	...	3·5	2·5	2·5	...	4·5	...	...	0·5	−0·3	8·5	...	...	4·3
	10. 17 30	34·7	5·7	5·5	6·6	5·5	7·7	3·3	−4·3	1·7	...	3·7	1·7	2·5	...	...	...	...	1·5	0·0	6·1	...	...	...
	12. 13 5	33·0	5·7	5·7	7·7	6·7	4·2	3·7	−3·9	−0·3	...	...	...	...	...	...	...	...	0·7	0·5	5·7	...	...	...
	13. 10 10	34·5	5·5	4·5	4·0	3·5	4·5	2·5	−2·5	2·5	...	...	...	...	...	...	...	...	1·3	1·3	4·0	...	...	...
	15. 4 15	38·0	5·9	5·0	6·5	5·7	7·0	2·5	−2·7	0·7	...	...	...	...	...	...	...	...	3·2	0·8	5·7	...	...	...
VIII.	Sept. 16. 11 20	58·7	6·0	3·7	...	...	4·7	...	...	...	...	4·2	2·7	3·4	3·5	3·5	...	1·2	...	...	...	...	...	...
	17. 12 30	61·9	6·9	3·5	...	...	5·0	...	...	...	...	4·1	2·2	3·6	4·2	3·8	...	2·5	...	...	...	...	...	...
	17. 13 20	60·4	6·5	4·3	...	...	4·2	...	...	...	...	4·2	2·1	3·4	3·3	3·4	...	2·3	...	...	...	...	...	...
	17. 15 20	59·4	6·9	4·4	...	...	3·7	...	...	...	...	3·8	2·7	2·8	2·7	3·6	...	2·4	...	...	...	...	...	...
	20. 13 0	52·8	6·1	4·4	...	...	4·8	...	...	...	...	4·0	...	...	...	3·6	...	2·8	...	...	7·2	...	...	...
	20. 13 50	51·4	6·7	4·6	...	...	5·2	...	...	...	...	...	...	...	...	4·1	...	3·0	...	...	8·4	...	...	...
	Oct. 2. 5 0	61·0	6·0	5·0	...	...	5·0	...	...	...	...	...	...	...	...	4·5	...	...	3·5	...	...	...	...	...
	2. 11 15	53·3	6·3	5·8	...	...	6·0	3·6	...	...	...	...	...	3·3	...	5·5	...	...	3·1	...	3·9	...	...	...
	5. 9 0	53·9	6·3	6·9	...	...	5·4	2·3	...	...	...	...	...	2·7	...	4·7	...	...	2·9	...	...	...	...	...
	5. 10 40	54·0	6·0	4·2	...	...	4·5	2·3	...	...	...	...	...	3·2	...	3·8	...	...	2·6	...	...	...	...	...
	12. 14 0	35·5	6·5	6·0	11·5	7·5	5·5	3·3	...	...	...	...	...	...	...	4·5	...	...	2·5	...	8·0	...	...	...
	12. 18 0	38·0	6·0	6·0	...	...	5·0	2·5	...	...	...	3·2	3·2	3·0	...	5·8	...	...	2·0	...	...	...	...	...
	12. 18 15	38·5	6·5	6·5	9·0	9·5	5·5	2·5	...	...	...	...	...	...	...	4·5	...	...	3·7	...	9·7	...	...	...
	13. 8 0	41·2	6·7	6·2	11·2	9·2	6·2	3·2	...	...	...	...	...	...	...	4·2	...	...	2·2	...	9·2	...	...	...
	16. 9 20	33·7	6·5	4·5	8·7	10·1	7·0	2·2	...	...	...	...	...	...	...	2·7	...	...	1·9	...	8·1	...	...	...
	16. 11 0	32·8	6·8	5·8	9·3	9·3	7·3	3·0	...	...	...	...	...	...	...	4·3	...	...	2·3	...	7·8	...	...	...
	16. 12 10	34·4	6·4	5·4	6·4	6·4	6·7	2·4	...	...	...	...	...	...	...	3·4	...	...	1·6	...	6·4	...	...	...
	16. 14 0	38·0	6·0	3·0	6·0	6·0	2·0	0·5	...	...	...	...	...	...	...	2·0	...	...	1·0	...	6·0	...	...	...
	17. 7 0	39·3	6·8	4·5	9·8	9·3	5·3	2·8	...	...	...	2·8	2·3	2·3	...	3·8	...	...	2·3	1·3	9·3	...	...	...
	18. 17 0	28·5	6·5	6·3	10·5	8·5	9·7	4·7	...	...	...	3·9	0·8	3·0	...	6·1	...	...	3·5	0·3	10·5	...	...	...
	19. 15 30	29·6	6·5	4·6	10·8	10·6	7·1	6·6	...	...	...	4·8	3·6	4·4	...	4·6	...	...	0·6	0·6	10·6	...	...	...
	19. 17 30	29·6	6·6	6·1	9·0	10·6	4·7	3·9	...	...	...	1·8	3·6	5·8	...	5·6	...	...	2·0	1·8	9·0	...	...	...
	19. 19 30	32·5	6·3	5·7	5·7	5·9	5·0	3·3	...	...	...	3·3	1·5	3·5	...	5·5	...	...	2·7	1·5	6·3	...	...	...
	21. 4 25	49·5	6·5	4·3	7·0	6·5	5·5	1·5	−0·5	0·0	...	1·3	2·5	2·7	...	4·0	...	...	2·5	2·0	6·0	...	...	...
	21. 11 30	39·0	6·7	4·5	9·0	8·0	5·3	2·6	−4·0	−1·3	...	3·0	2·0	2·4	...	2·8	...	...	0·6	0·2	6·5	...	...	...
	23. 5 0	50·3	6·5	4·1	8·0	6·5	4·9	1·4	−0·5	0·5	...	2·3	1·0	2·6	...	3·0	...	...	0·1	−0·3	7·1	...	...	...
	26. 5 10	43·5	6·7	2·8	5·0	5·0	3·1	2·0	−4·3	−2·4	...	1·7	0·3	1·3	...	1·7	...	...	−0·7	−0·9	5·0	...	...	...
	26. 15 30	33·1	6·3	3·5	6·4	6·7	4·1	2·6	−7·7	−5·0	...	2·6	4·3	1·7	...	3·8	...	...	1·1	0·0	6·3	...	...	...
	26. 19 0	33·3	6·3	4·3	6·7	7·1	3·0	2·5	−6·7	−8·0	...	2·3	4·3	3·5	...	4·7	...	...	1·3	1·3	5·3	...	...	...
	Nov. 8. 9 10	37·8	6·7	6·7	7·8	8·0	7·8	4·3	−3·4	4·8	...	4·1	3·8	4·1	...	5·8	...	...	2·6	1·8	8·6	...	...	5·8
	8. 11 0	36·6	6·6	6·6	8·6	8·6	7·1	3·6	−4·5	4·6	...	4·6	3·6	4·6	...	6·6	...	...	1·8	1·6	8·6	...	...	6·1
	8. 12 40	41·4	6·4	5·9	7·9	5·9	5·9	1·4	−1·6	1·4	...	1·6	0·9	1·9	...	...	...	...	0·2	0·2	7·4	...	...	4·3
IX.	Sept. 16. 9 10	61·5	7·6	8·3	...	...	5·5	...	...	...	...	6·0	0·7	3·6	4·5	7·5	...	3·7	...	...	...	...	...	...
	17. 11 0	62·3	7·0	6·0	...	...	5·3	...	...	...	...	3·8	1·5	3·3	3·8	4·3	...	2·7	...	...	...	...	...	...
	17. 11 30	62·4	7·6	6·6	...	...	5·6	...	...	...	...	4·5	2·0	4·2	4·3	4·6	...	2·7	...	...	...	...	...	...
	18. 7 30	66·1	7·8	6·3	...	...	6·6	...	...	...	...	5·1	1·8	4·0	3·8	5·5	...	3·4	...	...	...	...	...	...
	20. 10 50	54·5	7·5	5·5	...	...	4·5	...	...	...	...	...	...	3·5	...	7·0	...	3·0	...	...	7·5	...	...	...
	20. 11 20	54·2	7·7	6·0	...	...	6·2	...	...	...	...	4·2	...	...	...	4·2	...	3·0	...	...	8·7	...	...	...
	20. 14 30	51·7	7·3	5·0	...	...	4·7	...	...	...	...	...	...	3·4	...	4·3	...	2·9	...	...	8·7	...	...	...
	24. 17 35	47·5	7·1	7·7	...	...	8·4	2·5	...	...	...	...	2·8	...	...	5·0	...	3·2	...	...	7·5	...	...	...
	27. 18 0	40·4	7·9	6·6	...	...	6·0	4·4	...	...	...	...	5·4	...	...	5·9	...	4·4	...	...	9·9	...	...	...
	27. 18 22	39·7	7·5	7·4	...	...	7·9	3·2	...	...	...	...	...	4·9	...	4·7	...	3·7	...	...	8·2	...	...	...
	27. 19 10	41·0	7·0	6·2	...	...	6·5	...	...	...	...	...	...	4·5	...	5·0	...	3·5	...	...	9·0	...	...	...
	Oct. 5. 5 20	60·3	7·3	6·1	...	...	5·8	0·8	...	...	...	...	−0·2	...	...	3·7	...	...	2·9	...	...	...	...	...

Oct. 25, 21h 0m; the ice in evaporator is 0·5 in thickness three hours after sun-rise. Nov. 3, 5h 30m; scud and vapour. Nov. 7, 11h 10m; dew abundant. Sept. 16, 11h 20m; a great deposition of moisture. Sept. 17, 12h 30m; the stars nearly obscured. Sept. 17, 13h 20m; a few stars visible in the zenith. Sept. 20, 13h 0m; dew. Sept. 20, 13h 50m; dew. Oct. 2, 5h 0m; zenith clear. Oct. 12, 18h 15m; zenith clear. Oct. 17, 7h 0m; shortly after rain had fallen. Nov. 8, 9h 10m; no dew. Sept. 16, 9h 10m; the stars look small. Sept. 17, 11h 0m; zenith clear. Sept. 20, 11h 20m; dew. Sept. 20, 14h 30m; dew. Sept. 27, 18h 0m; hoar-frost. Sept. 27, 18h 22m; hoar-frost; the sun up. Sept. 27, 19h 10m; hoar-frost disappearing.

Oct. 25, 20h 0m. On examining the several substances at this time, it was found that cotton wool was covered with spikes of ice one-sixteenth of an inch in thickness: on raw wool there were a few flakes of clear ice, and a few spikes; also each fibre was encrusted with small round particles of ice: on blue and yellow wool the spikes were abundant, and all were inclined to the horizon at an angle of 30°: on every fibre of raw silk there were two spikes emanating from the same point and at right angles to the fibre, and inclined to the horizon at an angle of 30°: on black-lead, which substance was white with hoar-frost very early, there were clusters of spikes one-tenth of an inch in length, and inclined to the horizon at all angles: on charcoal there were clusters of spikes: on whiting there were spikes at all angles: on flannel the spikes were one-eighth of an inch in length: on saw-dust the spikes were in bunches, many of which were of a fan-like shape: and on wood there were many spikes.

Oct. 13, 20h 40m. After this observation, the three substances, raw wool, cotton wool and flax, were frequently examined, for the purpose of ascertaining the time t[illegible] [illegible]stance became free from dew; the sun was shining on all of them; it was noticed at 22h 30m that flax was free; at 14d 1h 30m cotton wool was *just* [illegible] *wool small drops of* water continued throughout the day.

Table (Continued).

Excess of the reading of the thermometer in air above that placed																							Clouds.			Wind.		
On coarse flax on grass.	On yellow cotton wool on grass.	On yellow cotton wool on raised board.	On blue cotton wool on grass.	On blue cotton wool on raised board.	On white wadding on grass.	On black wadding on grass.	On flannel on grass.	On flannel on raised board.	On raw silk on grass.	On raw silk on raised board.	On silk from cocoon.	On the raised board.	On saw-dust on the raised board.	On black-lead on raised board.	On charcoal on raised board.	On lamp-black on raised board.	On whiting on raised board.	On chalk on raised board.	On tinfoil.	On lead.	On pantile.	On slate.	One-fourth of an inch above water.	On paper on raised board.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.
5·6	°	4·3	...	4·3	...	...	...	6·6	...	4·3	...	3·3	3·0	4·3	5·6	...	4·3	...	...	...	...	...	...	...	Clear				
5·3	5·2	4·6	...	4·1	...	...	...	4·0	4·4	...	...	4·8	2·8	5·6	5·4	...	3·4	...	...	...	...	...	2·1	...				
8·3	...	5·2	...	...	...	...	...	3·5	...	4·1	...	3·3	...	4·1	3·9	...	4·1	4·7	...	...	...	...	2·1	...	.....	2			
6·2	4·7	...	5·3	...	5·7	...	5·0	...	6·0	...	...	...	...	...	...	...	...	...	3·3	5·0	3·7	4·3	2·3	...	Clear	...	...	S.	2
7·5	4·5	...	3·5	...	5·5	...	4·3	...	6·7	...	...	...	...	...	...	...	...	...	2·7	4·3	2·7	3·5	1·7	...	.....	...	...	S.	1·2
6·5	...	...	...	...	...	...	...	...	...	...	...	...	...	2·7	2·7	...	...	...	...	2·6	3·3	2·7	...	...	Cirrostratus	7			
7·7	...	...	...	...	2·7	3·7	4·7	...	4·9	...	...	...	...	2·7	1·7	2·7	4·7	3·2	0·7	1·7	2·7	2·5	...	...	Cirrostratus	10	H.		
3·5	...	...	...	...	3·3	3·3	3·3	...	4·7	...	...	...	...	4·7	3·3	4·0	4·5	5·6	0·5	2·5	3·0	2·5	...	...	Cirrostratus	10	H.		
6·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·0	2·7	2·8	...	...	Cirrostratus	10	H.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear				
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thin clouds	1			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·8	4·0	...	...	...	...	...	...	...	...	...	Clear				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·7	4·2	...	...	...	...	...	...	...	...	...	Clear				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thin clouds	9			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·2	...	...	...	...	...	...	...	...	...	Thin cirrost.	10	H.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·3	5·6	...	...	...	...	...	...	...	...	...	Clear				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·0	4·0	...	...	...	...	...	...	...	...	...	Cirrostratus	10			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thin clouds	5	...	N.	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thin clouds	4			
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...	...	...	...	...	...	...	...	...	...	0·3	0·3	...	4·3	2·3	5·3	...	...	...	...	...	...	...	...	...	Nimbus ...	8			
...	...	10·2	...	8·7	...	...	...	8·5	...	9·3	4·3	7·3	4·2	6·7	6·8	...	7·3	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	8·1	...	7·8	...	...	...	6·6	...	5·6	4·4	5·4	...	6·6	6·3	...	7·4	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	8·6	...	8·6	...	...	...	7·6	...	7·2	5·3	5·1	3·0	6·4	6·1	...	7·6	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	6·0	...	6·7	...	...	...	5·5	...	4·5	4·5	5·3	3·2	6·2	6·5	...	6·5	...	...	...	...	...	...	...	Clear	...	...	c.	
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...	...	6·0	...	6·0	...	...	...	6·5	...	6·4	...	3·2	3·2	5·8	4·8														
...	...	4·0	...	5·5	...	...	...	5·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	G.	
...	...	3·3	...	2·3	...	...	...	1·7	...	1·7	...	0·8	2·2	2·7	1·5	...	2·2	...	...	...	...	...	1·0	1·8	Clear	...	...	c.	
...	...	5·3	...	5·1	...	...	...	5·3	...	5·1	...	2·8	3·1	4·0	5·1	...	3·8	...	...	...	...	...	1·4	5·9	Clear	...	...	c.	
...	...	5·5	...	4·5	...	...	...	4·5	...	4·5	...	2·6	2·5	3·6	3·7	...	4·5	...	...	...	...	...	2·0	4·7	Clear	...	...	c.	
...	4·0	...	8·0	...	7·6	...	5·8	...	5·3	...	...	...	...	...	...	...	...	...	3·8	5·8	4·6	...	...	...	Clear	...	...	N.	1
...	5·6	...	7·1	...	8·1	...	5·6	...	7·1	...	...	...	...	...	...	...	...	...	3·6	5·3	4·6	6·6	2·6	...	Clear	...	...	N.	1
...	...	...	...	...	5·3	5·1	5·4	...	5·4	...	...	...	...	...	...	...	...	...	2·4	4·4	2·4	2·2	0·4	...	Clear	...	...	c.	
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·7	4·3	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·5	6·4	...	...	...	...	...	...	...	...	...	Cirrostratus	9	...	c.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·9	5·8	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·5	5·3	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·5	4·5	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·5	4·1	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	

Oct. 19, 19h 30m. At 21h the whole of the thermometers were read again; that in air had increased to 38°·2, and an increase from 10° to 20° had taken place in the readings of the other thermometers.

Oct. 16, 11h. The thermometer in the reflector is covered with dew: there is hoar-frost on long grass: on raw wool there are many square pieces of ice one-twentieth of an inch in thickness: at 11h 25m one piece of ice was removed from raw wool, which was three-fourths of an inch in length, half an inch in breadth, and one-sixteenth of an inch in thickness: on cotton wool the ice is forming in flakes, and there are some frozen dew drops on the grass.

Oct. 16, 14h 50m. All the thermometers which were on substances, with frozen particles about them, continued to read 32° till this minute, and now they all read 39°; the increase of 7° must have been sudden. The circumstance of these readings continuing to read 32° for nearly three hours after the sky was cloudy, illustrates the effect of sensible heat becoming latent whilst the frozen particles were changing into a liquid state. At 17h 20m the clouds became broken and the sky was partially clear, rain having fallen within the interval; the reading of all the instruments decreased, but as the substances were all wet, it is probable that a part of the decrease was owing to evaporation; no use was therefore made of these observations.

Sept. 20, 10h 50m. At this time a sudden deposition of moisture took place whilst I was looking at the instruments, and they all became wet with dew, except that which was placed on sand. The readings of those instruments thus bedewed increased between 3° and 4°; the temperature of the air continued to decline as before, so that the difference between the temperature of the air and those of the bedewed substances became less by the above amounts.

TABLE (Continued).

Number of the Tables.	1843. Astronomical day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed																					
			On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On garden mould.	On gravel.	On river sand.	On river sand on the raised board.	One inch high above grass.	Two inches high above grass.	Three inches high above grass.	Six inches high above grass.	Twelve inches high above grass.	Ounwrought white cotton wool on grass.	Ounwrought white cotton wool on raised board.	On raw wool on raised board.	On flax on raised board.
	h m	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
IX. (Continued.)	Oct. 5. 7 20	55·4	7·4	6·6	...	...	5·2	0·9	...	...	...	...	1·4	...	...	4·6	...	...	3·2	...	...	...	...	...
	9. 10 20	44·5	7·7	5·3	...	...	5·2	5·1	...	...	...	...	1·7	2·0	...	5·0	...	...	4·0	...	...	...	...	...
	9. 11 10	44·0	7·7	6·0	...	...	5·4	3·5	...	...	...	6·0	2·6	...	...	6·0	...	...	4·3	...	...	...	...	...
	12. 11 0	37·1	7·1	3·6	...	...	5·1	2·8	...	...	...	3·1	2·3	2·6	...	3·6	...	...	2·1	...	...	...	...	...
	12. 11 23	36·8	7·0	4·8	7·8	8·8	5·3	2·8	...	...	...	...	...	...	...	3·8	...	...	2·3	...	8·8	...	...	...
	12. 12 0	36·5	7·0	4·7	9·0	8·5	5·5	3·5	...	...	...	...	...	...	...	4·2	...	...	2·3	...	9·0	...	...	...
	13. 5 15	43·5	7·5	5·5	...	...	5·5	1·5	...	...	...	3·5	1·5	1·5	...	4·0	...	...	1·5	...	...	...	...	...
	13. 18 55	37·6	7·9	7·0	7·8	9·9	8·2	3·6	...	...	...	...	...	...	...	5·3	...	...	4·1	...	10·6	...	...	...
	14. 9 30	36·8	7·4	6·3	7·8	9·3	8·2	2·8	...	...	...	...	...	...	...	5·0	...	...	3·1	...	8·1	...	...	...
	16. 7 20	35·0	7·8	5·7	8·2	12·0	7·2	2·6	...	...	...	...	...	...	...	4·0	...	...	1·8	...	8·8	...	...	...
	16. 11 25	33·8	7·8	5·8	10·3	10·5	7·8	2·8	...	...	...	...	...	...	...	3·8	...	...	2·0	...	9·0	...	...	...
	16. 12 0	34·0	7·0	6·0	9·0	10·0	7·5	2·0	...	...	...	...	...	...	...	3·5	...	...	1·2	...	8·0	...	...	...
	20. 9 20	42·1	7·1	4·1	7·3	9·1	5·1	1·4	− 1·9	−0·1	3·1	2·3	2·4	2·9	...	3·1	...	...	...	...	9·1	...	...	...
	20. 11 0	42·0	7·0	4·5	10·8	10·0	7·0	2·0	− 1·0	0·0	3·0	3·0	3·0	3·3	...	3·0	...	...	1·0	0·2	6·8	...	...	...
	25. 19 30	31·0	7·0	5·0	9·0	8·7	5·0	3·0	−10·3	−6·3	4·2	1·4	−0·2	0·6	...	4·2	...	...	1·4	1·3	7·5	6·2	...	...
	26. 11 30	35·6	7·2	4·9	5·8	8·4	5·6	3·1	− 6·4	−4·4	5·3	1·4	5·8	2·8	...	5·3	...	...	1·4	0·9	6·2	...	...	...
	Nov. 7. 7 30	46·2	7·6	7·4	14·2	11·9	9·0	4·5	− 1·6	5·2	7·2	...	3·4	3·6	...	7·2	...	...	3·0	1·2	12·2	...	...	...
	11. 9 50	37·5	7·0	7·0	10·3	9·5	9·7	2·2	− 0·5	3·5	...	4·5	3·5	3·7	...	...	...	...	3·1	1·7	7·7	...	...	7·5
	11. 12 0	35·5	7·5	6·5	10·9	9·5	7·8	3·5	− 1·9	1·5	...	3·5	2·5	4·2	...	...	...	...	1·4	0·5	7·5	...	...	7·5
X.	Sept. 13. 15 20	49·5	8·7	8·5	...	...	11·0	...	...	...	...	...	1·5	7·0	5·0	8·5	4·5	...	...	...	9·5	8·3	...	...
	15. 9 10	61·5	8·5	7·0	...	...	6·0	...	...	...	...	5·0	1·9	3·5	5·3	5·5	...	2·5	...	...	8·5	...	...	...
	18. 8 0	65·3	8·0	5·9	...	...	6·2	...	...	...	...	3·5	5·3	3·8	...	6·1	...	3·1	...	...	...	...	...	...
	18. 11 20	60·3	8·0	6·1	...	...	8·6	...	...	...	...	...	0·1	...	...	7·6	...	4·1	...	...	9·4	...	...	...
	20. 8 45	57·6	8·6	8·6	...	...	8·8	...	...	...	...	5·8	2·8	...	...	7·8	...	4·3	...	...	10·8	...	...	...
	20. 9 55	57·3	8·5	8·8	...	...	6·1	...	...	...	...	4·3	1·3	4·1	3·9	5·3	...	3·3	...	...	...	...	...	...
	20. 11 40	54·2	8·4	7·5	...	...	6·2	...	...	...	...	...	2·0	...	...	4·2	...	3·0	...	...	8·7	...	...	...
	20. 15 20	52·0	8·5	7·6	...	...	6·0	...	...	...	...	...	2·7	...	...	6·4	...	4·0	...	...	9·2	...	...	...
	21. 18 45	51·8	8·3	7·4	...	...	5·8	...	...	...	...	...	...	4·0	...	6·0	...	3·1	...	...	8·1	...	...	...
	23. 5 40	62·6	8·1	6·6	...	...	6·2	1·6	...	...	...	...	...	2·6	...	4·4	...	3·4	...	...	9·4	...	...	...
	23. 7 30	58·3	8·3	6·8	...	...	7·3	2·3	...	...	...	...	1·1	...	...	8·1	...	3·7	...	...	9·5	...	...	...
	23. 11 35	52·1	8·2	7·1	...	...	5·6	2·1	...	...	...	6·6	...	...	...	7·1	...	3·9	...	...	7·2	...	...	...
	24. 13 30	52·5	8·5	7·1	...	...	6·8	3·5	...	...	...	5·5	...	...	...	5·0	...	3·8	...	...	8·0	...	...	...
	27. 11 30	41·2	8·7	7·4	...	...	8·2	4·2	...	...	...	7·2	...	...	...	6·2	...	4·0	...	...	11·4	...	...	...
	27. 15 15	39·8	8·8	7·3	...	...	7·3	3·8	...	...	...	...	...	6·0	...	5·0	...	3·8	...	...	10·3	...	...	...
	27. 17 15	39·5	8·0	8·0	...	...	7·5	3·9	...	...	...	5·0	...	...	...	5·5	...	4·5	...	...	10·0	...	...	...
	27. 18 48	40·4	8·4	8·4	...	...	8·6	...	...	...	...	...	...	4·9	...	5·4	...	3·4	...	...	10·9	...	...	...
	Oct. 2. 7 30	57·4	8·4	8·9	...	...	8·5	4·8	...	...	...	...	...	5·4	...	7·4	...	4·6	...	...	9·4	...	...	...
	4. 7 30	58·0	8·0	7·0	...	...	5·0	3·2	...	...	...	3·0	...	...	...	5·5	...	3·7	...	...	8·8	...	...	...
	9. 9 20	45·5	8·1	5·5	...	...	6·3	2·9	...	...	...	...	0·3	1·5	...	6·3	...	4·0	...	...	...	...	...	...
	9. 15 10	40·1	8·6	8·6	...	...	6·6	4·1	...	...	...	2·6	...	2·1	...	8·1	...	3·9	...	...	...	...	...	...
	12. 13 10	36·2	8·0	6·2	12·2	9·2	6·7	4·0	...	...	...	...	...	...	...	4·8	...	3·2	...	...	9·7	...	...	...
	13. 18 0	38·4	8·8	6·9	7·1	6·9	8·0	3·3	...	...	...	...	...	...	...	5·4	...	...	3·9	...	9·6	...	...	...
	13. 18 20	38·1	8·4	6·5	6·8	6·5	7·7	3·6	...	...	...	...	...	...	...	5·3	...	...	4·1	...	9·1	...	...	...
	13. 18 40	37·6	8·1	7·1	8·8	11·0	8·6	3·6	...	...	...	...	...	...	...	5·9	...	...	4·2	...	11·6	...	...	...
	13. 19 20	37·2	8·7	7·0	10·2	9·2	8·4	3·1	...	...	...	...	...	...	...	5·5	...	...	4·2	...	9·7	...	...	...
	14. 5 25	44·6	8·9	7·4	12·0	11·6	8·2	3·6	...	...	...	...	...	...	...	5·4	...	...	3·9	...	11·6	...	...	...
	14. 7 10	39·5	8·8	7·3	10·8	10·7	8·7	3·5	...	...	...	...	...	...	...	5·6	...	...	3·5	...	10·0	...	...	...
	15. 17 20	30·5	8·7	8·7	...	11·0	10·7	5·3	...	...	...	...	...	...	...	9·3	...	...	5·3	...	11·7	...	...	...
	20. 5 20	45·6	8·9	4·6	10·2	9·1	11·0	...	− 1·6	0·8	...	2·0	1·4	3·0	...	3·1	...	...	0·6	−0·2	7·4	...	...	...
	21. 5 0	48·2	8·2	5·5	9·2	8·9	5·2	2·1	− 1·0	0·0	...	2·2	2·2	3·2	...	4·5	...	...	2·5	2·1	8·7	...	...	...
	25. 15 0	32·9	8·1	7·5	11·0	11·5	7·9	4·4	− 9·6	−3·4	...	2·8	−0·1	2·4	...	...	...	...	2·2	1·3	8·9	...	...	...
	25. 18 15	30·3	8·0	6·7	10·6	11·1	6·8	3·9	−11·0	−6·7	...	2·5	0·3	1·3	...	...	...	...	1·9	1·4	9·0	8·8	...	...
	26. 9 0	38·3	8·3	7·1	10·0	9·8	7·3	3·0	− 4·7	−1·7	...	2·7	2·3	2·7	...	...	...	...	1·3	0·8	8·3	...	...	...
	Nov. 1. 8 30	38·0	8·0	6·0	10·5	10·5	6·0	3·0	− 6·0	−4·0	...	2·5	−1·0	2·0	...	...	...	...	2·0	1·5	10·0	...	...	...
	11. 5 30	40·5	8·3	5·4	8·5	8·3	6·0	2·5	− 2·3	−2·5	...	1·7	1·3	2·4	...	...	...	...	5·3	1·3	8·8	...	...	8·3
	12. 20 30	30·6	8·6	7·6	10·1	9·8	6·1	3·9	− 4·2	0·6	...	...	...	...	...	...	...	...	2·6	2·3	9·6	...	...	...
	13. 9 0	33·0	8·1	6·0	9·2	8·6	8·4	3·5	− 4·0	2·0	...	...	...	...	...	...	...	...	1·9	1·7	7·0	...	...	...

Oct. 14, 9h 30m; the stars very dim. Sept. 15, 9h 10m; horizon thick. Sept. 21, 18h 45m; great deposition of moisture. Sept. 24, 13h 30m; the stars appear to be dim and small. Sept. 27, 15h 15m; hoar-frost. Sept. 27, 17h 15m; hoar-frost. Sept. 27, 18h 48m; hoar-frost.

Oct. 12, 11h 0m. The thermometer placed on long grass was thickly encrusted with hoar frost. At the time of the deposition of dew the readings of all the thermometers increased which became wetted by it; that is, of every instrument whose reading was less than the temperature of the dew-point. The first appearance of dew was in very minute drops on the pointed ends of long grass, which on receiving an increase of water flowed down the blades.

Oct. 21, 5h 0m. At this time 10 grains of wool were placed on grass, and a similar parcel was placed on the raised board; at 7h 30m the former was found to weigh 12·1 grains, and the latter 10·7 grains; the glass stems of all the thermometers were wet with dew, though the substances upon which they were placed were not yet wet; at 19h the weight of the parcel which was placed on grass was 17 grains, that placed on the raised board had blown away.

Nov. 12, 20h 0m. Wood was covered with spikes of ice one-fourth of an inch in thickness, inclined to the horizon at an angle of 60°, and at all azimuths; on

Table (Continued).

Excess of the reading of the thermometer in air above that placed																								Clouds.			Wind.		
on grass.	On yellow cotton wool on grass.	On yellow cotton wool on raised board.	On blue cotton wool on grass.	On blue cotton wool on raised board.	On white wadding on grass.	On black wadding on grass.	On flannel on grass.	On flannel on raised board.	On raw silk on grass.	On raw silk on raised board.	On silk from cocoon.	On the raised board.	On saw-dust on the raised board.	On black-lead on raised board.	On charcoal on raised board.	On lamp-black on raised board.	On whiting on raised board.	On chalk on raised board.	On tinfoil.	On lead.	On pantile.	On slate.	One-fourth of an inch above water.	On paper on raised board.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	5°5	5°9	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
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9·7	...	...	...	...	6·5	7·3	7·6	...	10·0	...	...	...	...	...	...	...	...	...	3·7	10·0	5·5	5·5	4·5	...	Clear	...	...	c.		
9·5	...	...	...	...	9·5	7·3	7·5	...	9·3	...	...	...	...	...	...	...	...	...	2·5	4·3	3·5	4·5	3·0	...	Clear	...	...	c.		
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Vap.
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...	7·2	...	7·2	...	...	...	...	...	7·2	...	...	2·2	3·0	4·7	5·0	...	7·4	...	...	...	...	...	...	...	.....	5				
1·6	...	9·9	...	9·3	...	...	...	8·4	...	9·7	9·9	7·1	4·9	8·9	8·7	...	8·9	...	...	...	...	...	2·6	...	Clear					
1·5	...	9·1	...	7·3	...	...	...	8·5	...	9·3	...	7·3	3·8	8·8	8·8	...	7·5	...	...	...	...	...	2·3	...	Clear					
9·8	...	8·1	...	7·3	...	...	...	5·8	...	7·5	4·0	4·2	5·1	6·1	5·2	...	5·8	...	...	...	...	...	4·2	6·8	Clear					
9·0	...	4·0	...	4·0	...	...	...	3·0	...	...	...	4·5	4·0	6·0	5·0	...	3·2	4·0	...	...	...	...	2·0	...	Clear					
9·3	...	...	...	...	...	...	...	...	6·3	...	...	...	...	...	...	...	...	...	2·5	3·5	2·5	3·5	2·0	...	Clear					
9·4	...	...	...	...	8·6	4·6	7·4	...	8·1	...	...	...	...	7·9	6·8	6·6	9·4	9·4	2·4	6·1	4·4	3·4	...	...	Clear					
8·0	...	...	...	...	6·0	7·0	6·0	...	...	...	...	...	...	6·0	3·0	6·5	7·0	6·5	2·0	6·8	2·2	3·2	...	...	Cirrostratus	9½				

arcoal and on black-lead there were spikes in rich clusters; those forming one cluster all emanated from the same point, and they were inclined at all angles; lampblack the spikes were very numerous, being about three-eighths of an inch in thickness, and inclined to the horizon at an angle of about 30°, and at all imuths, so that each cluster formed a circle, in the centre of which there were no spikes: on sand there were spikes one-fourth of an inch in length, inclined at angles to the horizon: chalk was covered with a mass of spikes one-fourth of an inch in length; whiting was covered with rich bunches of spikes three-eighths an inch in length: flat was covered with small sparkling flakes of ice: raw wool was encrusted on each fibre so as to be about six times its own size: cotton ool was completely covered with spikes, and paper was covered with small round particles and a few spikes.

Oct. 13, $17^h\ 50^m$. At this time the sky was overcast and the readings of all the thermometers were nearly alike; at $18^h\ 0^m$ the instruments were read exhibiting e above large differences.

Table (Continued).

Number of the Tables.	1843. Astronomical day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed: On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On garden mould.	On gravel.	On river sand.	On river sand on the raised board.	One inch high above grass.	Two inches high above grass.	Three inches high above grass.	Six inches high above grass.	Twelve inches high above grass.	On unwrought white cotton wool on grass.	On unwrought white cotton wool on raised board.	On raw wool on raised board.	On flax on raised board.
XI.	h m	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
	Sept. 15. 7 20	63·2	9·9	8·4	...	...	7·7	...	...	...	...	5·2	1·2	3·2	2·2	6·2	...	3·2	...	...	9·2	...	...	...
	15. 11 0	58·8	9·9	8·8	...	...	7·8	...	...	...	...	6·8	3·6	5·3	6·8	7·0	...	3·6	...	...	10·8	...	...	...
	16. 7 40	65·0	9·1	9·0	...	...	7·3	...	...	...	...	6·5	0·3	4·0	3·4	7·0	...	4·2	...	...	...	...	...	...
	18. 9 30	63·0	9·5	9·0	...	...	7·5	...	...	...	...	6·0	3·0	5·3	...	7·2	...	4·5	...	...	10·0	...	...	...
	19. 15 10	53·0	9·3	7·8	...	...	11·0	...	...	...	...	...	3·5	...	...	7·5	...	3·1	...	...	8·7	...	...	...
	20. 10 25	55·5	9·5	9·0	...	...	8·0	...	...	...	...	...	3·0	...	...	7·0	...	4·0	...	...	10·5	...	...	...
	20. 15 0	52·6	9·7	8·3	...	...	6·1	...	...	...	...	5·1	...	...	...	6·9	...	4·6	...	...	10·7	...	...	...
	21. 6 55	62·7	9·7	9·2	...	...	9·2	...	...	...	...	...	1·7	...	...	7·0	...	4·5	...	...	8·2	...	...	...
	21. 7 30	61·5	9·5	8·5	...	...	7·3	...	...	...	...	6·5	...	...	...	7·8	...	4·5	...	...	10·5	...	...	...
	21. 18 20	51·3	9·0	9·0	...	...	8·0	...	...	...	...	...	...	5·9	...	7·5	...	3·5	...	...	10·0	...	...	...
	23. 6 0	61·4	9·7	7·4	...	...	7·4	2·4	...	...	...	5·0	...	...	...	6·4	...	4·1	...	...	11·4	...	...	...
	24. 15 10	50·5	9·0	7·0	...	...	7·9	3·0	...	...	...	...	...	5·5	...	6·0	...	4·1	...	...	10·5	...	...	...
	28. 11 35	45·3	9·5	6·3	...	...	7·3	2·8	...	...	...	...	...	3·9	...	4·8	...	3·4	...	...	10·0	...	...	...
	28. 13 25	43·5	9·6	8·0	...	...	11·3	3·0	...	...	...	7·7	...	...	...	5·5	...	3·8	...	...	12·5	...	...	...
	Oct. 15. 4 50	41·0	9·2	7·1	11·7	12·8	7·6	2·7	...	...	...	...	...	...	...	5·0	...	...	3·0	...	11·8	...	...	...
	15. 5 5	40·5	9·8	7·8	11·7	13·2	9·1	3·2	...	...	...	...	...	...	...	6·2	...	...	3·1	...	12·3	...	...	...
	18. 5 20	42·2	9·8	6·9	12·9	...	7·9	2·8	...	...	...	5·2	4·0	3·9	...	5·2	...	...	3·0	2·1	9·4	...	...	...
	18. 8 30	35·7	9·7	8·9	11·6	8·2	8·7	3·4	...	...	...	5·7	4·5	4·7	...	6·5	...	...	4·5	3·5	11·7	...	...	...
	19. 7 40	35·6	9·6	7·8	12·4	12·1	8·6	3·9	−6·9	−1·1	...	5·4	2·4	3·8	...	6·6	...	...	2·6	1·8	10·5	...	...	...
	19. 10 0	33·2	9·0	8·7	11·7	14·7	7·4	4·0	−6·8	−2·3	...	2·7	1·7	2·7	...	6·2	...	...	2·3	1·8	10·4	...	...	...
	19. 12 0	31·0	9·5	8·5	13·0	12·8	7·8	3·8	...	...	...	1·8	0·8	3·0	...	8·0	...	...	1·9	0·8	11·5	...	...	...
	21. 9 20	42·1	9·9	7·8	12·9	11·3	7·1	3·5	−1·1	−1·3	...	4·7	2·9	4·9	...	7·5	...	...	3·3	2·9	9·9	...	...	...
	25. 13 0	35·5	9·3	8·0	12·1	12·5	7·9	4·7	−7·5	−0·5	...	4·5	1·9	3·0	...	6·5	...	...	1·9	1·1	9·5	...	...	...
	26. 7 35	40·5	9·3	2·8	10·1	8·9	6·5	3·1	−3·5	−1·0	...	3·0	1·2	3·5	...	5·5	...	...	1·3	0·7	8·0	...	...	...
	Nov. 8. 12 0	35·5	9·5	8·3	12·0	11·8	9·3	4·3	−4·5	1·5	...	4·0	4·0	4·0	...	6·5	...	...	3·5	2·7	12·0	...	...	...
	8. 13 0	35·1	9·1	7·9	11·6	11·6	9·1	4·1	−4·1	1·1	...	4·1	4·1	3·6	...	5·6	...	...	3·0	2·3	11·6	...	...	...
	8. 17 0	33·5	9·0	8·0	11·2	9·5	8·5	3·5	−4·5	1·0	...	4·0	3·0	4·5	...	6·0	...	...	2·7	2·2	11·2	...	...	...
	9. 5 30	33·0	9·5	9·5	13·5	13·0	11·5	3·5	−6·0	−1·5	...	2·5	3·2	3·0	...	...	...	...	3·2	2·9	13·0	...	...	...
	10. 19 30	33·5	9·3	7·5	10·5	10·5	9·3	2·5	−4·3	−0·7	...	2·0	1·2	2·0	...	...	...	...	2·5	1·5	10·5	...	...	...
	11. 7 30	38·8	9·8	8·7	13·8	13·2	9·5	3·3	−1·6	1·8	...	6·0	4·2	4·8	...	...	...	...	3·8	2·6	13·7	...	...	10·2
	11. 10 35	37·0	9·2	9·5	10·8	10·5	8·8	3·8	−1·0	3·0	...	5·0	4·0	4·0	...	...	...	...	3·8	2·8	10·0	...	...	7·4
	12. 13 5	31·7	9·5	7·2	11·0	10·8	6·0	5·5	−6·2	0·0	...	...	...	...	...	...	...	...	1·0	1·0	7·2	...	...	...
XII.																								
	Sept. 15. 10 33	59·5	10·0	7·9	...	...	8·0	...	...	...	...	5·5	2·3	5·0	...	6·5	...	3·5	...	...	12·0	...	...	...
	18. 9 0	64·0	10·0	9·0	...	...	7·0	...	...	...	...	8·0	3·0	8·0	...	7·0	...	5·5	...	...	10·0	...	...	...
	19. 10 0	59·2	10·7	9·5	...	...	9·2	...	...	...	...	...	4·2	...	...	9·2	...	4·7	...	...	11·2	...	...	...
	19. 11 10	55·5	10·5	10·3	...	...	10·3	...	...	...	...	...	2·5	...	...	9·0	...	5·3	...	...	11·1	...	...	...
	19. 13 10	53·7	10·7	7·7	...	...	11·7	...	...	...	...	...	3·7	...	...	7·1	...	4·4	...	...	6·7	...	...	...
	20. 9 25	57·7	10·2	9·2	...	...	9·2	4·2	...	...	...	...	...	3·7	...	7·7	...	4·2	...	...	10·6	...	...	...
	21. 6 10	63·6	10·1	7·4	...	...	...	...	...	...	...	...	...	4·5	...	5·3	...	4·3	...	...	9·9	...	...	...
	22. 5 40	62·6	10·1	9·2	...	...	7·2	...	...	...	...	4·1	...	...	...	5·9	...	3·8	...	...	12·3	...	...	...
	22. 7 20	58·3	10·6	10·5	...	...	9·3	...	...	...	...	...	0·6	...	...	8·1	...	4·5	...	...	12·7	...	...	...
	22. 8 10	56·2	10·5	10·3	...	...	7·4	...	...	...	...	...	...	5·0	...	7·2	...	4·3	...	...	11·2	...	...	...
	22. 11 30	52·0	10·9	12·0	...	...	9·5	3·6	...	...	...	...	...	...	...	7·8	...	4·8	...	...	11·5	...	...	...
	22. 13 30	50·7	10·0	8·5	...	...	8·7	3·6	...	...	...	...	2·2	...	...	7·7	...	3·5	...	...	9·9	...	...	...
	23. 8 30	56·5	10·5	9·3	...	...	7·5	3·0	...	...	...	...	...	6·5	...	8·5	...	4·1	...	...	11·5	...	...	...
	23. 10 50	52·8	10·8	8·3	...	...	7·8	2·8	...	...	...	...	...	7·1	...	8·8	...	4·8	...	...	12·3	...	...	...
	23. 11 10	52·2	10·7	9·1	...	...	7·2	2·7	...	...	...	7·5	...	...	...	8·6	...	4·6	...	...	12·2	...	...	...
	26. 11 30	41·4	10·1	10·0	...	...	9·1	3·9	...	...	...	...	...	3·9	...	8·6	...	4·2	...	...	11·4	...	...	...
	27. 9 10	41·5	10·7	9·3	...	...	10·5	5·2	...	...	...	9·5	...	...	...	5·8	...	5·5	...	...	11·5	...	...	...
	27. 11 0	41·5	10·0	7·7	...	...	8·0	4·3	...	...	...	...	...	6·7	...	7·0	...	4·3	...	...	11·5	...	...	...
	Oct. 2. 7 25	57·0	10·5	9·5	...	...	8·5	4·8	...	...	...	...	2·5	...	...	9·0	...	4·5	...	...	11·8	...	...	...
	15. 15 20	29·8	10·0	9·4	...	...	10·8	5·3	...	...	...	...	...	...	...	9·4	...	...	3·6	...	...	...	...	...
	18. 7 40	38·0	10·0	8·0	13·3	...	7·6	2·4	...	...	...	4·6	4·0	4·3	...	6·5	...	...	2·8	1·7	10·0	...	...	...
	18. 9 30	36·8	10·8	8·8	12·8	10·8	9·8	3·8	...	...	...	6·8	6·1	5·9	...	7·8	...	...	4·8	3·4	13·8	...	...	...
	18. 14 30	30·6	10·8	9·8	14·6	14·7	10·9	5·1	...	...	...	4·4	3·6	5·1	...	8·1	...	...	4·1	3·3	12·8	...	...	...
	18. 18 0	30·0	10·4	8·9	12·0	12·0	12·8	5·2	...	...	...	4·8	2·9	5·8	...	8·9	...	...	4·5	4·0	13·2	...	...	...
	19. 4 30	43·5	10·3	7·0	13·5	11·6	7·0	2·1	...	...	...	7·9	0·7	2·8	...	5·0	...	...	2·3	1·6	11·5	...	...	...
	19. 8 10	35·9	10·7	10·7	15·9	15·9	11·4	4·9	−6·1	0·9	...	5·1	3·7	6·1	...	9·1	...	...	3·9	3·2	13·7	...	...	...
	21. 7 30	44·0	10·0	7·8	12·5	12·5	7·5	3·5	−4·0	−0·5	...	4·5	2·8	4·0	...	6·0	...	...	2·0	2·5	10·2	...	...	...
	25. 9 30	38·2	10·4	8·2	13·2	13·2	7·2	4·2	−6·8	−0·2	...	3·7	1·0	0·7	...	7·7	...	...	1·2	0·7	13·0	11·7	...	...
	25. 11 40	36·6	10·4	8·4	12·6	12·8	8·4	3·6	−5·7	0·9	...	5·1	2·6	3·6	...	7·5	...	...	1·8	1·4	10·8	11·0	...	...
	Nov. 7. 5 30	51·7	10·5	9·7	13·7	11·4	9·7	4·2	2·6	5·7	...	4·1	4·1	5·4	...	7·6	...	...	4·5	1·7	11·7	...	...	...
	12. 19 20	33·0	10·0	7·9	10·4	11·0	7·4	5·8	−6·2	1·2	...	...	...	...	...	...	...	...	2·7	2·3	9·0	...	...	...

Sept. 15, 11h 0m; a thin cloud passing zenith. Sept. 18, 9h 30m; the stars seem small. Sept. 19, 15h 10m; the stars seem small, and they have a watery appearance. Sept. 20, 15h 0m; deposition of moisture. Sept. 21, 6h 55m; the clouds are confined to the zenith and around it. Sept. 21, 7h 30m; the clouds are confined to the zenith and around it. Sept. 21, 18h 20m; deposition of moisture. Sept. 24, 15h 10m; the stars are dim and small. Sept. 28, 11h 35m; a few clouds near S. horizon, and the stars are dim. Sept. 28, 13h 25m; stars seem small and shine dimly. Oct. 19, 7h 40m; dew just forming. Sept. 19, 10h 0m; a few clouds. Sept. 19, 11h 10m; stars seem small and watery. Sept. 19, 13h 10m; stars seem small and watery. Sept. 23, 10h 50m; the south portion of sky very clear. Sept. 23, 11h 10m; the stars have become dim. Oct. 2, 7h 25m; dew being deposited. Oct. 19, 8h 10m; dew. Oct. 21, 7h 30m; dew.

Oct. 19, 7h 40m. At 7h 0m a parcel of 10 grains of wool was placed on grass, and at this time it was found to weigh 11 grains. The temperature of the air at 7h 40m was 3° less than it was 7h 0m, and yet the differences between the readings of the several thermometers and that in air, is less by 2° or 3° the

Table (Continued).

Excess of the reading of the thermometer in air above that placed																									Clouds.			Wind.		
on grass.	On yellow cotton wool on grass.	On yellow cotton wool on raised board.	On blue cotton wool on grass.	On blue cotton wool on raised board.	On white wadding on grass.	On black wadding on grass.	On flannel on grass.	On flannel on raised board.	On raw silk on grass.	On raw silk on raised board.	On silk from cocoon.	On the raised board.	On saw-dust on the raised board.	On black-lead on raised board.	On charcoal on raised board.	On lamp-black on raised board.	On whiting on raised board.	On chalk on raised board.	On tinfoil.	On lead.	On pantile.	On slate.	One-fourth of an inch above water.	On paper on raised board.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°						
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·0	8·7	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Mist
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·0	6·6	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
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7·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Haz.
2·1	...	11·4	...	10·8	...	...	...	8·4	...	11·4	9·4	7·6	5·8	7·4	7·6	...	7·8	...	...	...	...	...	...	...	Clear	...	...	...	...	Haz.
2·2	...	8·0	...	9·0	...	...	...	7·2	...	10·2	7·7	5·4	4·2	6·5	6·2	...	6·2	...	...	...	...	...	...	...	Clear	...	...	c.		
9·8	...	10·0	...	10·0	...	...	...	8·8	...	10·0	7·7	4·8	4·0	7·7	7·5	...	7·8	...	...	...	...	...	...	...	Clear	...	...	c.		
2·9	...	9·6	...	9·4	...	...	...	8·9	...	10·8	...	5·1	3·9	8·1	6·9	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
2·5	...	10·5	...	10·5	...	...	...	8·5	...	9·1	10·2	7·5	5·2	8·0	7·4	...	8·5	...	...	...	...	...	3·5	...	Clear	...	...	c.		
0·5	...	6·2	...	5·4	...	...	...	2·3	...	6·3	...	3·5	4·3	5·5	4·7	...	4·9	...	...	...	...	...	...	4·5	Clear	...	...	c.		
9·9	10·5	...	10·5	...	9·3	9·7	7·5	...	10·3	...	...	...	...	...	...	...	...	...	6·3	9·0	4·3	6·5	4·5	...	Clear	...	...	N.		
0·1	9·1	...	9·1	...	8·1	8·6	8·1	...	9·9	...	...	...	...	...	...	...	...	...	4·1	6·1	4·1	6·1	3·1	...	Clear	...	...	N.		
9·5	7·5	...	8·5	...	7·5	8·5	6·5	...	8·5	...	...	...	...	...	...	...	...	...	5·0	6·5	6·3	6·5	3·0	...	Clear	...	...	N.		
3·0	10·0	...	9·0	...	11·5	...	9·0	...	9·5	...	...	...	...	...	...	...	...	...	4·8	7·5	3·2	6·0	4·0	...	.....	2				
3·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·3	4·3	2·3	4·7	2·3	...	Clear	...	...	c.		
3·3	...	...	...	...	8·8	7·0	8·8	...	10·0	...	...	...	...	...	...	...	...	...	6·8	7·0	6·6	6·7	4·4	...	Clear	...	...	c.		
1·4	...	...	...	...	5·8	7·0	9·0	...	10·5	...	...	...	...	...	...	...	...	...	4·8	6·0	5·5	6·0	4·0	...	Clear	...	...	c.		
0·0	...	...	...	...	8·0	...	5·8	...	7·0	...	...	...	...	7·0	6·0	7·0	...	9·0	2·4	5·0	3·0	4·6	...	...	Thin clouds	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·7	6·2	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·7	5·9	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·7	8·7	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·9	5·2	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·0	6·1	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·0	2·6	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·0	5·9	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·2	7·3	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·7	9·2	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·7	7·0	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·9	5·8	...	...	...	...	...	...	...	...	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·9	6·6	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·2	7·2	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·2	7·2	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·0	7·8	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·3	9·0	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Haz.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·5	8·0	...	...	...	...	...	...	...	...	...	Nearly clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	2		...	...	Fog.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	...	...	Haz.
0·8	...	11·8	...	9·8	...	...	...	9·3	...	12·2	10·3	...	...	6·5	7·3	...	5·8	...	...	...	...	...	...	...	Clear	...	...	...	...	Haz.
3·6	...	12·5	...	12·6	...	...	...	12·4	...	13·6	9·9	8·4	5·6	9·4	9·6	...	11·6	...	...	...	...	...	...	...	Clear	...	...	L.		
2·0	...	13·8	...	13·6	...	...	...	10·8	...	10·2	11·8	11·3	6·9	10·8	11·4	...	12·0	...	...	...	...	...	...	...	Clear	...	...	L.		
0·9	...	5·0	...	5·2	...	...	...	4·9	...	9·1	4·4	2·9	3·7	3·3	2·7	...	6·0	...	...	...	...	...	...	...	Cirrus	½				
5·4	...	13·7	...	13·4	...	...	...	12·7	...	13·2	11·7	8·9	6·7	8·7	9·1	...	10·3	...	...	...	...	...	...	...	Clear	...	...	c.		
0·2	...	10·0	...	10·0	...	...	...	10·6	...	10·2	...	5·8	5·0	7·0	7·0	...	...	...	...	...	...	...	...	...	Clear					
2·9	...	12·2	...	13·0	...	...	...	11·4	...	10·2	...	8·4	7·0	7·9	7·0	...	9·7	...	...	...	...	...	3·7	...	Clear	...	...	...	...	Haz.
2·9	...	11·5	...	11·4	...	...	...	8·9	...	9·3	...	8·4	5·6	8·6	8·1	...	9·6	...	...	...	...	...	4·4	...	Clear	...	...	...	...	Haz.
1·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·7	...	Clear					
2·0	...	8·9	...	8·0	...	...	...	8·4	...	8·8	...	...	...	5·6	4·4	6·7	7·2	7·0	3·2	7·0	3·8	5·7	...	...	Clear	...	...	c.		

the former time (see Table XIV.). It would seem from this circumstance that the heat evolved at the time of the deposit of dew was about 4°. At Oct. 19, 21^h the wool was found to weigh 21 grains, and the thickness of ice in the evaporator was found to be 0·5 inch.

Oct. 15, 4^h 35^m. At this time the thermometers were placed on their different substances, and large differences were almost immediately exhibited.

Oct. 19, 4^h 30^m. These observations were taken two hours before sun-set; during the whole of this day the temperature of vegetation in the shade was much below the temperature of the air; at 19^d 1^h the reading of a thermometer on grass was 39°·0, whilst that in air was 47°·2.

Oct. 25, 11^h 40^m. The water which was placed in the evaporating dish exposed to the whole sky is frozen, whilst that placed in a similar dish exposed to one-half of the sky only is not frozen.

Table (Continued).

Number of the Tables.	1841. Astronomical day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed																						
			On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On garden mould.	On gravel.	On river sand.	On river sand on the raised board.	One inch high above grass.	Two inches high above grass.	Three inches high above grass.	Six inches high above grass.	Twelve inches high above grass.	On unwrought white cotton wool on grass.	On unwrought white cotton wool on raised board.	On raw wool on raised board.	On flax on raised board.
XI.	h m	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
	Sept. 15. 7 20	63·2	9·9	8·4	…	…	7·7	…	…	…	…	5·2	1·2	3·2	2·2	6·2	…	3·2	…	…	9·2	…	…	…	…
	15. 11 0	58·8	9·9	8·8	…	…	7·8	…	…	…	…	6·8	3·6	5·3	6·8	7·0	…	3·6	…	…	10·8	…	…	…	…
	16. 7 40	65·0	9·1	9·0	…	…	7·3	…	…	…	…	6·5	0·3	4·0	3·4	7·0	…	4·2	…	…	…	…	…	…	…
	18. 9 30	63·0	9·5	9·0	…	…	7·5	…	…	…	…	6·0	3·0	5·3	…	7·2	…	4·5	…	…	10·0	…	…	…	…
	19. 15 10	53·0	9·3	7·8	…	…	11·0	…	…	…	…	…	3·5	…	…	7·5	…	3·1	…	…	8·7	…	…	…	…
	20. 10 25	55·5	9·5	9·0	…	…	8·0	…	…	…	…	…	3·0	…	…	7·0	…	4·0	…	…	10·5	…	…	…	…
	20. 15 0	52·6	9·7	8·3	…	…	6·1	…	…	…	…	5·1	…	…	…	6·9	…	4·6	…	…	10·7	…	…	…	…
	21. 6 55	62·7	9·7	9·2	…	…	9·2	…	…	…	…	…	1·7	…	…	7·0	…	4·5	…	…	8·2	…	…	…	…
	21. 7 30	61·5	9·5	8·5	…	…	7·3	…	…	…	…	6·5	…	…	…	7·8	…	4·5	…	…	10·5	…	…	…	…
	21. 18 20	51·3	9·0	9·0	…	…	8·0	…	…	…	…	…	…	5·9	…	7·5	…	3·5	…	…	10·0	…	…	…	…
	23. 6 0	61·4	9·7	7·4	…	…	7·4	2·4	…	…	…	5·0	…	…	…	6·4	…	4·1	…	…	11·4	…	…	…	…
	24. 15 10	50·5	9·0	7·0	…	…	7·9	3·0	…	…	…	…	…	5·5	…	6·0	…	4·1	…	…	10·5	…	…	…	…
	28. 11 35	45·3	9·5	6·3	…	…	7·3	2·8	…	…	…	…	…	3·9	…	4·8	…	3·4	…	…	10·0	…	…	…	…
	28. 13 25	43·5	9·6	8·0	…	…	11·3	3·0	…	…	…	7·7	…	…	…	5·5	…	3·8	…	…	12·5	…	…	…	…
	Oct. 15. 4 50	41·0	9·2	7·1	11·7	12·8	7·6	2·7	…	…	…	…	…	…	…	5·0	…	…	3·0	…	11·8	…	…	…	…
	15. 5 5	40·5	9·8	7·8	11·7	13·2	9·1	3·2	…	…	…	…	…	…	…	6·2	…	…	3·1	…	12·3	…	…	…	…
	18. 5 20	42·2	9·8	6·9	12·9	…	7·9	2·8	…	…	…	5·2	4·0	3·9	…	5·2	…	…	3·0	2·1	9·4	…	…	…	…
	18. 8 30	35·7	9·7	8·9	11·6	8·2	8·7	3·4	…	…	…	5·7	4·5	4·7	…	6·5	…	…	4·5	3·5	11·7	…	…	…	…
	19. 7 40	35·6	9·6	7·8	12·4	12·1	8·6	3·9	−6·9	−1·1	…	5·4	2·4	3·8	…	6·6	…	…	2·6	1·8	10·5	…	…	…	…
	19. 10 0	33·2	9·0	8·7	11·7	14·7	7·4	4·0	−6·8	−2·3	…	2·7	1·7	2·7	…	6·2	…	…	2·3	1·8	10·4	…	…	…	…
	19. 12 0	31·0	9·5	8·5	13·0	12·8	7·8	3·8	…	…	…	1·8	0·8	3·0	…	8·0	…	…	1·9	0·8	11·5	…	…	…	…
	21. 9 20	42·1	9·9	7·8	12·9	11·3	7·1	3·5	−1·1	−1·3	…	4·7	2·9	4·9	…	7·5	…	…	3·3	2·9	9·9	…	…	…	…
	25. 13 0	35·5	9·3	8·0	12·1	12·5	7·9	4·7	−7·5	−0·5	…	4·5	1·9	3·0	…	6·5	…	…	1·9	1·1	9·5	…	…	…	…
	26. 7 35	40·5	9·3	2·8	10·1	8·9	6·5	3·1	−3·5	−1·0	…	3·0	1·2	3·5	…	5·5	…	…	1·3	0·7	8·0	…	…	…	…
	Nov. 8. 12 0	35·5	9·5	8·3	12·0	11·8	9·3	4·3	−4·5	1·5	…	4·0	4·0	4·0	…	6·5	…	…	3·5	2·7	12·0	…	…	…	…
	8. 13 0	35·1	9·1	7·9	11·6	11·6	9·1	4·1	−4·1	1·1	…	4·1	4·1	3·6	…	5·6	…	…	3·0	2·3	11·6	…	…	…	…
	8. 17 0	33·5	9·0	8·0	11·2	9·5	8·5	3·5	−4·5	1·0	…	4·0	3·0	4·5	…	6·0	…	…	2·7	2·2	11·2	…	…	…	…
	9. 5 30	33·0	9·5	9·5	13·5	13·0	11·5	3·5	−6·0	−1·5	…	2·5	3·2	3·0	…	…	…	…	3·2	2·9	13·0	…	…	…	…
	10. 19 30	33·5	9·3	7·5	10·5	10·5	9·3	2·5	−4·3	−0·7	…	2·0	1·2	2·0	…	…	…	…	2·5	1·5	10·5	…	…	…	…
	11. 7 30	38·8	9·8	8·7	13·8	13·2	9·5	3·3	−1·6	1·8	…	6·0	4·2	4·8	…	…	…	…	3·8	2·6	13·7	…	…	…	10·2
	11. 10 35	37·0	9·2	9·5	10·8	10·5	8·8	3·8	−1·0	3·0	…	5·0	4·0	4·0	…	…	…	…	3·8	2·8	10·0	…	…	…	7·4
	12. 13 5	31·7	9·5	7·2	11·0	10·8	6·0	5·5	−6·2	0·0	…	…	…	…	…	…	…	…	1·0	1·0	7·2	…	…	…	…
XII.																									
	Sept. 15. 10 33	59·5	10·0	7·9	…	…	8·0	…	…	…	…	5·5	2·3	5·0	…	6·5	…	3·5	…	…	12·0	…	…	…	…
	18. 9 0	64·0	10·0	9·0	…	…	7·0	…	…	…	…	8·0	3·0	8·0	…	7·0	…	5·5	…	…	10·0	…	…	…	…
	19. 10 0	59·2	10·7	9·5	…	…	9·2	…	…	…	…	…	4·2	…	…	9·2	…	4·7	…	…	11·2	…	…	…	…
	19. 11 10	55·5	10·5	10·3	…	…	10·3	…	…	…	…	…	2·5	…	…	9·0	…	5·3	…	…	11·1	…	…	…	…
	19. 13 10	53·7	10·7	7·7	…	…	11·7	…	…	…	…	…	3·7	…	…	7·1	…	4·4	…	…	6·7	…	…	…	…
	20. 9 25	57·7	10·2	9·2	…	…	9·2	4·2	…	…	…	…	…	3·7	…	7·7	…	4·2	…	…	10·6	…	…	…	…
	21. 6 10	63·6	10·1	7·4	…	…	…	…	…	…	…	…	…	4·5	…	5·3	…	4·3	…	…	9·9	…	…	…	…
	22. 5 40	62·6	10·1	9·2	…	…	7·2	…	…	…	…	4·1	…	…	…	5·9	…	3·8	…	…	12·3	…	…	…	…
	22. 7 20	58·3	10·6	10·5	…	…	9·3	…	…	…	…	…	0·6	…	…	8·1	…	4·5	…	…	12·7	…	…	…	…
	22. 8 10	56·2	10·5	10·3	…	…	7·4	…	…	…	…	…	…	5·0	…	7·2	…	4·3	…	…	11·2	…	…	…	…
	22. 11 30	52·0	10·9	12·0	…	…	9·5	3·6	…	…	…	…	…	…	…	7·8	…	4·8	…	…	11·5	…	…	…	…
	22. 13 30	50·7	10·0	8·5	…	…	8·7	3·6	…	…	…	…	2·2	…	…	7·7	…	3·5	…	…	9·9	…	…	…	…
	23. 8 30	56·5	10·5	9·3	…	…	7·5	3·0	…	…	…	…	…	6·5	…	8·5	…	4·1	…	…	11·5	…	…	…	…
	23. 10 50	52·8	10·8	8·3	…	…	7·8	2·8	…	…	…	…	…	7·1	…	8·8	…	4·8	…	…	12·3	…	…	…	…
	23. 11 10	52·2	10·7	9·1	…	…	7·2	2·7	…	…	…	7·5	…	…	…	8·6	…	4·6	…	…	12·2	…	…	…	…
	26. 11 30	41·4	10·1	10·0	…	…	9·1	3·9	…	…	…	…	…	3·9	…	8·6	…	4·2	…	…	11·4	…	…	…	…
	27. 9 10	41·5	10·7	9·3	…	…	10·5	5·2	…	…	…	9·5	…	…	…	5·8	…	5·5	…	…	11·5	…	…	…	…
	27. 11 0	41·5	10·0	7·7	…	…	8·0	4·3	…	…	…	…	…	6·7	…	7·0	…	4·3	…	…	11·5	…	…	…	…
	Oct. 2. 7 25	57·0	10·5	9·5	…	…	8·5	4·8	…	…	…	…	2·5	…	…	9·0	…	4·5	…	…	11·8	…	…	…	…
	15. 15 20	29·8	10·0	9·4	…	…	10·8	5·3	…	…	…	…	…	…	…	9·4	…	…	3·6	…	…	…	…	…	…
	18. 7 40	38·0	10·0	8·0	13·3	…	7·6	2·4	…	…	…	4·6	4·0	4·3	…	6·5	…	…	2·8	1·7	10·0	…	…	…	…
	18. 9 30	36·8	10·8	8·8	12·8	10·8	9·8	3·8	…	…	…	6·8	6·1	5·9	…	7·8	…	…	4·8	3·4	13·8	…	…	…	…
	18. 14 30	30·6	10·8	9·8	14·6	14·7	10·9	5·1	…	…	…	4·4	3·6	5·1	…	8·1	…	…	4·1	3·3	12·8	…	…	…	…
	18. 18 0	30·0	10·4	8·9	12·0	12·0	12·8	5·2	…	…	…	4·8	2·9	5·8	…	8·9	…	…	4·5	4·0	13·2	…	…	…	…
	19. 4 30	43·5	10·3	7·0	13·5	11·6	7·0	2·1	…	…	…	7·9	0·7	2·8	…	5·0	…	…	2·3	1·6	11·5	…	…	…	…
	19. 8 10	35·9	10·7	10·7	15·9	15·9	11·4	4·9	−6·1	0·9	…	5·1	3·7	6·1	…	9·1	…	…	3·9	3·2	13·7	…	…	…	…
	21. 7 30	44·0	10·0	7·8	12·5	12·5	7·5	3·5	−4·0	−0·5	…	4·5	2·8	4·0	…	6·0	…	…	2·0	2·5	10·2	…	…	…	…
	25. 9 30	38·2	10·4	8·2	13·2	13·2	7·2	4·2	−6·8	−0·2	…	3·7	1·0	0·7	…	7·7	…	…	1·2	0·7	13·0	11·7	…	…	…
	25. 11 40	36·6	10·4	8·4	12·6	12·8	8·4	3·6	−5·7	0·9	…	5·1	2·6	3·6	…	7·5	…	…	1·8	1·4	10·8	11·0	…	…	…
	Nov. 7. 5 30	51·7	10·5	9·7	13·7	11·4	9·7	4·2	2·6	5·7	…	4·1	4·1	5·4	…	7·6	…	…	4·5	1·7	11·7	…	…	…	…
	12. 19 20	33·0	10·0	7·9	10·4	11·0	7·4	5·8	−6·2	1·2	…	…	…	…	…	…	…	…	2·7	2·3	9·0	…	…	…	…

Sept. 15, 11h 0m; a thin cloud passing zenith. Sept. 18, 9h 30m; the stars seem small. Sept. 19, 15h 10m; the stars seem small, and they have a watery appearance. Sept. 20, 15h 0m; deposition of moisture. Sept. 21, 6h 55m; the clouds are confined to the zenith and around it. Sept. 21, 7h 30m; the clouds are confined to the zenith and around it. Sept. 21, 18h 20m; deposition of moisture. Sept. 24, 15h 10m; the stars are dim and small. Sept. 28, 11h 35m; a few clouds near S. horizon, and the stars are dim. Sept. 28, 13h 25m; stars seem small and shine dimly. Oct. 19, 7h 40m; dew just forming. Sept. 19, 16h 6m; a few clouds. Sept. 19, 11h 10m; stars seem small and watery. Sept. 19, 13h 10m; stars seem small and watery. Sept. 23, 10h 50m; the south portion of sky very cle… 23, 11h 10m; the stars have become dim. Oct. 2, 7h 25m; dew being deposited. Oct. 19, 8h 10m; dew. Oct. 21, 7h 30m; dew.

Oct. … At 7h 0m a parcel of 10 grains of wool was placed on grass, and at this time it was found to weigh 11 grains. The temperature of the air at 7h 40m … it was 7h 0m, and yet the differences between the readings of the several thermometers and that in air, is less by 2° or 3° than they were

Table (Continued).

Excess of the reading of the thermometer in air above that placed																							Clouds.			Wind.		
On coarse flax on grass.	On yellow cotton wool on grass.	On yellow cotton wool on raised board.	On blue cotton wool on grass.	On blue cotton wool on raised board.	On white wadding on grass.	On black wadding on grass.	On flannel on grass.	On flannel on raised board.	On raw silk on grass.	On raw silk on raised board.	On silk from cocoon.	On the raised board.	On saw-dust on the raised board.	On black-lead on raised board.	On charcoal on raised board.	On lamp-black on raised board.	On whiting on raised board.	On chalk on raised board.	On tinfoil.	On lead.	On pantile.	On slate.	One-fourth of an inch above water.	On paper on raised board.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°						
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	3				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	1				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·1	8·7	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·1	8·5	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·7	9·0	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Vap.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·5	8·3	...	...	...	...	...	...	...	...	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·7	9·2	...	...	...	...	...	...	...	...	...	Nearly clear					
11·8	...	11·0	...	11·1	...	...	...	8·8	...	10·8	11·6	8·8	6·8	7·6	8·8	...	7·8	...	...	...	...	...	...	...	Clear	...	...	...	...	Haze
13·5	...	11·0	...	11·5	...	...	...	8·5	...	12·0	12·0	9·5	5·5	7·5	8·6	...	7·5	...	...	...	...	...	...	...	Clear	...	...	...	...	Haze
13·8	...	10·5	...	12·7	...	...	...	9·5	...	12·5	11·5	9·2	6·5	9·0	8·8	...	9·2	...	...	...	...	...	...	...	Clear					
14·0	...	12·5	...	12·3	...	...	...	9·5	...	12·5	10·5	7·3	5·0	7·3	7·5	...	11·0	...	...	...	...	...	...	...	Clear	...	...	c.	...	Haze
13·8	...	11·6	...	11·6	...	...	...	11·3	...	10·7	...	7·8	6·8	9·0	7·9	...	8·8	...	...	...	...	...	4·8	...	Clear					
12·9	...	9·7	...	8·9	...	...	...	7·7	...	7·5	...	6·0	5·7	6·9	4·5	...	6·5	...	...	...	...	...	3·7	7·5	.....	1				
11·6	...	4·6	...	4·6	...	...	...	2·6	...	5·6	...	5·0	...	...	3·8	...	5·4	...	...	...	...	...	2·4	...	Clear					
13·0	...	7·8	...	9·2	...	...	...	9·0	...	9·0	...	5·2	...	8·5	7·0	...	7·0	7·0	8·0	...	...	...	3·0	...	Clear					
14·0	...	5·0	...	5·0	...	...	...	6·0	...	6·0	...	6·0	...	6·2	6·0	...	7·5	7·5	7·0	...	...	...	5·0	...	Clear	...	...	c.	...	Fog.
13·0	...	6·5	...	8·0	...	...	8·6	6·5	12·5	...	...	9·5	...	6·2	5·8	...	6·4	6·0	...	...	5·5	5·5	2·8	...	Clear					
14·9	...	...	...	...	7·5	7·0	...	...	...	...	...	...	...	6·0	6·2	7·3	6·5	7·1	5·7	...	5·9	6·3	...	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·0	3·5	...	...	...	...	...	...	...	...	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
14·2	...	11·7	...	12·7	...	...	...	11·7	...	13·3	10·5	8·0	8·0	8·3	10·0	...	9·3	...	...	...	...	...	...	...	Clear	...	...	c.	...	Haze
15·3	...	9·6	...	9·6	...	...	...	9·6	...	12·6	8·6	7·0	6·6	7·0	7·6	...	7·8	...	...	...	...	...	...	...	Clear					
16·4	...	10·4	...	10·8	12·8	13·3	9·3	9·3	...	11·9	9·9	7·2	7·2	6·4	7·6	...	7·2	...	...	...	...	...	...	...	Clear	...	...	c.		
13·3	10·3	...	12·1	...	...	...	...	...	9·8	...	...	...	...	...	...	...	...	...	6·3	9·3	5·8	7·3	2·8	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	10·4	7·8	11·5	11·2	10·4	...	...	...	...	...	...	Clear	...	...	c.		
16·0	...	...	...	...	15·5	12·8	...	...	13·0	...	...	...	...	9·8	7·0	9·8	9·5	9·8	5·0	9·0	5·0	8·0	...	...	Clear	...	...	c.		
15·8	...	...	...	...	12·8	11·3	12·8	...	12·3	...	...	...	...	10·1	6·8	10·5	10·5	10·3	4·8	9·1	5·1	7·8	...	...	Clear	...	...	c.		
14·5	...	...	...	...	12·5	13·5	12·5	...	10·5	...	...	...	...	8·5	7·5	10·5	7·5	9·5	5·5	9·3	6·0	9·5	...	...	.....	3				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·6	7·1	9·4	7·1	8·7	...	...	...	...	...	...	Clear					
12·0	...	...	...	...	9·4	9·0	10·5	...	9·2	...	...	...	...	8·0	7·0	10·5	9·0	9·5	5·0	8·2	5·2	7·0	...	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	8·4	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	7·2	...	...	...	...	...	...	...	...	...	...	...	...	.....	1				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·5	9·2	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	13·4	...	14·4	...	14·9	...	...	...	...	15·3	12·2	10·4	7·2	9·9	10·9	...	10·2	...	...	...	...	...	...	...	Clear	...	...	c.		
...	11·0	...	12·0	...	11·0	...	...	...	...	12·2	7·6	9·3	4·8	8·5	11·0	...	9·8	...	...	...	...	...	...	...	Clear	...	...	c.		
...	16·5	...	12·2	...	12·5	...	...	...	...	13·3	11·5	9·8	8·1	7·5	9·7	...	8·3	...	...	...	...	...	...	...	Clear	...	...	c.		
...	15·8	...	14·5	...	14·5	14·6	12·6	12·6	14·6	14·3	11·3	8·5	...	10·5	10·3	...	10·0	...	...	...	...	...	6·0	...	Clear	...	...	c.		
...	18·5	...	...	...	...	...	...	...	...	...	...	...	...	9·6	7·1	10·6	9·6	...	5·1	8·4	3·5	7·1	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	8·3	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	...	...	...	...	...	...	...	...	...	...	...	8·2	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		
...	16·5	...	13·8	...	14·1	...	...	...	...	16·1	12·1	10·1	9·3	10·3	11·5	...	10·1	...	...	...	...	...	...	...	Clear	...	...	c.		

Nov. 1, 4ʰ 25. An inch of rain had fallen previously, and at this time the sky became suddenly clear; dry substances were placed, and immediately the above large differences were exhibited.

Nov. 12, 8ʰ 30ᵐ. The reading of the thermometer on coarse flax was 18°·5 below that in air (see Table XV.); and Nov. 13, at 5ʰ 10ᵐ, the difference between the readings of the thermometer in air and that on raw wool was as large as 19°·5 (see Table XIV.). These differences were greater than any hitherto met with by any person, and especial care was taken so as to be certain of their correctness.

TABLE (Continued).

Number of the Tables.	1852. Astronomical day, hour and minute.	Reading of Thermr. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer as above that thermr.																										
			On long grass.	On short grass.	On raw wool on grass	On flue on grass	In focus of reflector	Nine inches above wool	One inch in low surface of ground under short grass	On surface of ground under short grass	On surface of ground under long grass	On garden mould.	On gravel.	On river sand.	On river equal on the raised board	One inch high above grass.	Two inches high above grass	Three inches high above grass	Six inches high above grass	Twelve inches high above grass	On raw wool on white cotton wool on grass.	On raw wool on white cotton wool on raised board.	On raw wool on raised board.	On flue on raised board.
XIII.	Sept. 18. 15 15	49·8	11·5	10·5			11·6									10·5					12·5			
	18. 15 30	52·4	11·4	10·4																	11·7			
	18. 15 30	54·7	11·2	9·2			9·6														12·5			
	18. 15 45	56·5	11·3	9·3			9·8														12·3			
	18. 16 0	47·9	11·7	10·7																	12·1			
	18. 16 15	44·5	11·1	9·5																	11·7			
	18. 16 30	44·4	11·1	9·3																	11·4			
	18. 16 45	43·5	11·1	9·1																	11·4			
	18. 17 0	40·5	11·1	9·1																	11·4			
	18. 17 15	39·1	11·1	10·1																	11·4			
	Oct. 15. 10 30	52·6	11·6	9·5	11·5	11·5	11·6	4·5				5·5	5·5	5·5		9·5			4·5	5·5	12·5	10·5		
	15. 11 0	53·5	11·5	9·5	11·5	11·5	11·6	4·5				5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 11 30	52·6	11·6	9·7	11·6	11·6	11·6	4·5				5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 12 0	51·5	11·4	9·6	11·5	11·5	11·6	4·5				5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 12 30	51·1	11·4	9·6	11·5	11·5	11·6	4·5	−1·1	−1·5		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 13 0	50·6	11·4	9·6	11·5	11·5	11·6	4·5	−1·1	−1·5		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 13 30	49·5	11·3	9·6	11·5	11·5	11·6	4·5	−1·1	−1·5		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	15. 14 0	48·6	11·4	9·6	11·5	11·5	11·6	4·5	−1·1	−1·4		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	Nov. 1. 4 30	45·4	11·1	9·4	11·4	11·4	11·6	4·5	−1·1	−1·4		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	1. 5 0	40·2	11·4	9·4	11·4	11·4	11·6	4·5	−1·1	−1·4		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	4. 5 30	47·6	11·6	9·6	11·5	11·4	11·6	4·5	−1·0	−1·4		5·5	5·5	5·5		9·5			4·5	5·5	12·5			
	12. 6 0	37·5	11·4	11·5	11·5	11·4	11·6	4·5	−1·0	−1·5														
XIV.	Sept. 27. 5 30	47·4	12·2	9·5			7·4					4·5				9·5		4·5			14·5			
	Oct. 16. 5 30	39·4	12·4	9·4	12·4	12·4	12·6	4·5				5·5				9·5			4·5		14·5			
	16. 12 0	42·5	12·1	10·1	12·1	12·1	12·6	4·5				5·5	4·5			9·5			4·5	4·5	14·5			
	16. 5 0	47·4	12·4	9·5	12·4	12·4	12·6	4·5				5·5	5·5			9·5			4·5	5·5	14·5			
	16. 5 30	46·4	12·4	10·5	12·4	12·4	12·6	4·5				5·5	5·5			9·5			4·5	5·5	14·5			
	Nov. 9. 5 0	41·9	12·3	9·5	12·4	12·4	12·6	4·5	−0·7	0·7		5·5	5·5	4·5		9·5			4·5	5·5	14·5			
	10. 4 45	37·6	12·4																					
	12. 5 30	35·4	12·4	12·4	12·4	12·4	12·6	4·5	−1·1	1·1									4·5	4·5	12·5			12·5
	12. 10 30	32·9	12·5	12·1	12·5	12·5	12·6	4·5	−1·0	1·0											12·5			
	13. 5 30	37·4	12·5	11·5	12·5	12·4	12·6	4·5	−1·0	1·0											12·5			
	15. 5 30	37·4	12·6																					
	15. 6 0	36·4	12·5	12·4	12·4	12·4	12·6	4·5	−0·9	0·9											12·5			
XV.	Sept. 15. 11 30	51·4	12·5	12·4			12·6						4·5											
	15. 12 0	50·5	12·5	12·5			12·6						5·5	4·5	4·5	12·5	4·5					9·5		
	15. 14 30	50·4	12·4	12·4			12·6						4·5	5·5	4·5	12·5	4·5				11·5	10·5		
	19. 13 15	48·9	12·5	12·5			12·6	4·5				6·5				12·5		6·5			12·5			
	Oct. 14. 15 0	52·4	12·5	10·4	12·4	12·4	12·6	4·5				4·5	5·5	5·5		9·5			4·5	5·5	14·5			13·5
	14. 15 0	52·4	12·5	9·5	12·5	12·5	12·6	4·5	4·5			4·5	5·5	5·5		9·5			4·5	5·5	12·5			9·5
	14. 5 30	40·5	12·4	10·4	12·4	12·4	12·6	4·5	4·5			6·5	5·5	5·5		9·5			4·5	5·5	13·5			10·5
	20. 5 15	45·0	12·4	10·5	12·5	12·5	12·6	4·5	−0·5	0·5		9·5	5·5	5·5		9·5			4·5	4·5	13·4	10·5		13·5
	Nov. 12. 6 30	32·6	12·5	12·4	12·5	12·5	12·6	4·5	−0·5	0·5									4·5	4·5	13·1			
XVI.	Sept. 14. 12 30	50·5	11·4	10·5			11·6						4·5	5·5	4·5	10·5	4·5					11·5		
	15. 13 30	50·5	11·5	10·5			11·6						5·5	5·5	4·5	10·5	4·5				11·5	11·5		
	Oct. 14. 6 15	40·5	12·1	11·5	12·5	12·5	12·6	4·5				7·5	4·5	5·5		10·5			4·5	5·5	13·5			11·5

Sept. 15, 13h 15m: the sky is cloudy to 50° high. Sept. 15, 14h 20m: clouds all round to 50° high. Sept. 15, 14h 40m: a few clouds to the north. Nov. 13, 5h 10m: dark clouds. Sept. 15, 11h 15m: great deposition of moisture. Sept. 15, 12h 0m: great deposition of moisture. Sept. 15, 14h 30m: great deposition of moisture. Sept. 15, 15h 15m: the stars shine, and dim. Sept. 15, 12h 30m: great deposition of moisture. Sept. 15, 13h 30m: great deposition of moisture.

Sept. 27, 12h 0m: Dew has been deposited previous to this observation: the thermometer placed in long grass was covered with dew-drops, as must as that in short had to be wiped before the reading could be taken: that placed on raw wool was similarly circumstanced, and it was firmly frozen in the wool.

Oct. 15, 12h 0m: The thermometer is white with dew-drops: wool and flue are each a mass of ice, and the thermometers are firmly frozen in them. The thickness of ice at the temperature was 0·5 inch.

sky, arranged according to the difference of the readings of the one on Long Grass and that in Air, from observations between 1843, Nov. 16, and the end of the year 1843.

Excess of the reading of the thermometer in air above that placed																								Clouds.			Wind.		
On lambs' wool on grass.						On zinc on grass.			On tin.						On stone.														
Yellow.	Crimson.	Scarlet.	On copper on grass.	On lead on grass.	On iron on grass.	Thick.	Of moderate thickness.	Thin.	White on grass.	White one inch high.	Blackened on grass.	On tin-foil.	On pantile.	On slate.	Firestone.	Purbeck.	Portland.	On brick.	On glass on grass.	On glass one inch high.	On unwrought white cotton wool on grass.	On the raised board.	One-fourth of an inch above water.	On coarse flax on grass.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°					
...	...	.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	2·5	2·3	1·2	...	...	...	2·0	...	...	...	1·8	2·4	1·6	...	...	0·7	...	1·0	...	...	0·7	...	Cirrostratus	10	...	...	2	
...	...	...	0·0	2·0	−0·6	...	...	0·1	0·0	...	1·4	...	1·5	1·6	...	...	...	1·6												
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	4·2	...	2·5	...	...	...	2·5	2·7	4·5	...	...	...	1·7	...	...	1·7	3·9	3·8	...	...	...	...	Cirrostratus	10				
...	...	...	...	4·0	...	...	...	...	...	...	...	2·7	2·9	4·7	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10				
...	...	...	...	5·7	...	3·7	3·9	2·5	...	...	...	...	2·5	3·9	...	...	...	...	...	...	...	...	1·5	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·0	...	...	...	Cirrostratus	10				
3·5	3·0	2·0	3·3	2·7	2·6	...	...	...	2·8	...	...	...	2·0	2·0	1·8	...	...	1·3	...	...	...	...	...	4·5	.....	1	...	w.	1	
...	...	...	3·5	2·3	2·9	...	...	...	4·5	...	...	...	2·8	3·0	1·9	...	...	1·7	...	...	...	...	2·8	...	Clear	...	...	w.	1	
...	...	...	3·0	3·2	2·5	...	...	...	3·5	...	...	...	2·7	3·2	1·5	...	...	1·0	...	...	...	...	0·7	...	Clear	...	...	w.	1	
...	...	...	3·3	2·1	4·0	4·5	4·7	4·0	3·3	4·0	5·0	...	2·0	2·2	2·5	...	...	3·0	5·7	6·0	...	...	1·0	...	Cirrostratus	10	...	w.	1	
...	...	...	4·7	4·5	3·7	4·2	3·2	3·2	5·0	3·5	4·7	...	4·0	4·0	4·7	...	...	3·0	2·7	3·0	...	...	...	...	Wh. fleecy cl	7	...	w.	L.	
...	...	...	4·0	4·4	3·8	3·2	3·5	3·5	3·0	3·0	4·5	...	3·7	5·2	3·0	2·5	2·0	...	4·5	3·0	...	...	1·7	...	Cirrostratus	10				
...	...	...	3·2	4·0	3·2	3·1	3·5	3·2	...	...	3·9	...	...	...	1·9	1·7	1·7	2·5	4·2	2·3	...	...	...	...	Clear					
...	...	...	...	2·6	...	...	4·2	2·2	...	...	3·0	...	...	...	...	...	...	...	2·6	1·4	...	...	...	...	Clear					
...	...	...	...	4·0	...	...	...	...	...	...	...	3·2	2·7	2·8	...	...	...	...	...	...	5·7	...	...	...	Cirrostratus	10				
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	...	2	
...	...	...	...	3·5	...	...	...	...	...	...	...	...	3·1	3·8	...	...	...	...	...	...	...	3·5	...	2·5	Clear					
...	...	...	...	3·5	...	...	...	...	...	...	...	...	3·2	3·8																
4·7	3·7	3·4	3·3	2·8	3·8	...	...	...	...	...	...	...	2·8	3·8	3·0	...	...	2·8	...	...	...	...	1·8	...	.....	5	...	w.	L.	Vap.
2·9	2·3	2·3	4·3	2·8	3·3	...	...	...	3·3	...	...	...	3·2	3·4	2·3	...	...	1·9	...	...	...	...	1·6	...	Cirrus	5	...	w.	1	
4·1	2·3	3·3	3·2	2·2	2·4	...	...	...	2·9	...	...	...	2·6	2·7	2·1	...	...	1·6	...	...	...	...	1·9	...	Cirrus	5	...	w.	1	
...	...	...	4·3	4·0	2·6	3·8	3·9	1·8	2·6	2·3	8·3	...	2·8	3·3	1·8	...	...	1·8	4·6	2·8	...	...	1·0							
...	...	...	4·7	4·7	3·5	4·3	4·7	4·5	5·0	4·3	4·7	...	3·3	4·3	2·7	...	...	...	4·3	4·0	...	...	...	...	Clear					
...	...	...	4·4	3·4	3·5	4·2	4·1	4·6	4·4	4·2	4·8	...	3·2	3·2	3·0	...	...	2·9	5·1	3·2	...	...	2·2	...	Clear					
...	...	...	4·5	2·9	3·5	3·7	3·7	3·9	3·5	3·7	4·2	*	...	...	2·2	2·4	1·9	...	4·9	3·5	...	...	...	...	Thin clouds	8	H.			
...	...	...	4·9	1·4	3·5	4·5	4·5	4·5	3·5	2·8	4·2	...	...	...	2·5	2·6	2·5	...	4·9	3·2	...	...	...	...	.....	3	...	w.	½	
...	...	...	3·9	3·8	3·8	3·8	3·8	4·0	...	...	4·6	...	...	...	2·9	2·6	2·9	2·8	3·8	2·5	...	...	...	...	Clear					
...	...	...	3·9	...	3·9	...	...	...	...	...	3·4	...	...	...	2·0	...	...	...	4·1	...	...	...	...	...	Clear					
...	...	...	3·5	3·5	3·8	...	3·5	3·3	4·0	3·5	4·2	...	...	...	3·0	3·8	2·8	...	4·2	2·5	...	...	...	...	Clear					
...	...	...	...	3·8	...	...	...	...	...	...	...	...	2·3	3·8	...	...	...	...	...	...	6·0	...	...	6·0	.....	10				
4·6	3·3	3·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Nearly clear					
...	...	...	4·7	3·5	3·8	...	...	...	4·0	...	...	...	4·5	4·2	3·7	...	...	2·7	...	...	...	...	2·7	...	.....	2	...	c.	...	Vap.
...	...	...	4·5	3·3	3·8	...	...	...	3·1	...	...	...	3·5	4·0	3·8	...	...	2·9	...	...	...	...	2·0							
...	...	...	6·5	4·9	4·2	...	...	...	3·7	...	...	...	2·9	3·9	1·5	...	...	2·2	...	...	...	...	2·2	...	.....	5	...	s.e.	L.	
...	...	...	4·6	3·4	3·9	...	...	...	3·5	...	...	...	3·6	3·8	2·3	...	...	2·3	...	...	...	...	2·1	...	Cirrus	2				
...	...	...	5·0	5·6	4·6	...	...	...	6·0	...	...	...	4·7	5·6	4·8	...	...	1·8	...	...	...	...	1·8							
...	...	...	6·1	5·6	4·6	5·3	5·3	5·6	5·4	...	5·5	...	2·6	4·7	...	...	...	...	5·6	...	...	...	...	...	Clear					
...	...	...	6·3	5·6	4·7	5·8	5·5	5·8	5·5	...	5·5	...	2·4	4·7	...	...	...	...	5·5	...	...	...	...	...	Clear					
...	...	...	...	4·2	4·4	...	...	...	4·4	...	3·6	...	4·4	4·4	...	...	...	...	5·4	...	...	...	2·1	...	Clear					
...	...	...	5·0	4·5	4·2	4·8	4·5	5·0	4·0	3·5	4·8	...	4·0	4·0	3·8	...	...	3·8	4·5	3·0	...	...	1·5	...	Wh. fleecy cl	7	...	w.	L.	
...	...	...	4·8	4·2	4·0	4·8	4·8	4·8	3·8	4·0	5·8	...	...	...	3·0	4·0	3·0	3·8	5·5	5·0	...	...	1·0							
...	...	...	4·6	4·6	3·4	5·3	5·2	5·6	3·6	3·6	4·3	...	...	...	2·3	2·6	1·9	1·8	4·6	3·5	...	...	0·6							
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	1				
...	...	...	5·2	4·1	3·2	4·2	4·2	4·2	3·4	3·2	4·4	...	...	...	2·6	2·9	2·2	...	4·6	2·9	...	...	...	...	Clear		...	...	¾	

one and two feet high were 45°; the readings of those placed on long grass, short grass, raw wool and flax were all 41°·5, and those on all metals read 43°; the temperature on the surface of the ground was 42°·5, and the air was in gentle motion from the west; yet there was a small portion of dew on most substances, which seems anomalous as the temperature of the dew-point was 40°.

Table (Continued).

Number of the Tables.	1843, Day, hour and minute.	Reading of Therm. at the height of 4 feet above the soil, protected from radiation.	Excess of the reading of the thermometer in air above that placed																									
			On long grass.	On short grass.	On raw wool on grass.	On flax on grass.	In focus of reflector.	Nine inches above wood.	One inch below surface of ground under short grass.	On surface of ground under short grass.	On surface of ground under long grass.	On long grass covered by							On garden mould.	Six inches high above grass.	One foot high above grass.	Two feet high above grass.	On lambs' wool on grass.					
												White raw wool.	Flax.	White tin.	White tin one inch high.	Blackened tin.	Glass.	Glass one inch high.					Jet black.	White.	Green.	Light blue.	Dark blue.	Orange.
XXIII.	Nov. 18. 7 30	39·8	7·3	6·8	8·8	8·8	7·0	1·8	−1·5	2·2	...	...	...	...	...	...	...	...	0·6	1·0	...	3·6	4·0	3·8	5·1	3·6	3·8
	23. 12 0	36·5	7·0	6·3	8·0	8·5	8·0	2·5	−3·5	−1·0	...	...	...	...	...	...	...	...	4·0	...	0·0	0·0	...	...	...	...	...	...
	29. 4 40	46·7	7·7	6·7	9·7	8·7	6·1	2·7	1·2	2·9	...	...	...	...	...	...	...	...	...	...	1·7	1·2	...	...	...	...	...	...
	29. 11 0	42·8	7·8	7·8	7·8	8·8	7·8	2·3	3·8	−0·2	...	...	...	...	...	...	...	...	...	...	1·3	1·3	...	...	...	...	...	...
	Dec. 2. 3 40	40·8	7·0	5·9	5·8	6·9	6·8	1·6	−4·0	3·7	2·4	...	...	2·5	2·3	...	3·4	2·8	...	...	0·3	0·2	...	...	...	...	...	...
	2. 4 30	39·5	7·9	6·5	9·0	9·3	6·7	2·0	−4·3	1·2	2·2	...	...	2·2	2·5	...	4·2	3·0	...	...	−0·3	−0·5	...	...	...	...	...	...
	6. 4 15	45·8	7·6	6·8	8·4	6·8	6·3	2·2	0·4	3·0	2·5	...	...	3·3	3·3	...	4·8	4·0	...	...	0·8	0·5	...	...	...	...	...	...
	7. 19 0	49·0	7·0	6·0	9·0	6·5	5·0	2·0	2·7	4·0	2·2	...	...	...	...	...	3·0	...	...	...	−0·3	−0·3	...	...	...	...	...	...
	7. 21 0	45·0	7·3	5·8	7·8	6·6	6·0	1·8	4·6	5·6	3·8	...	...	...	4·8	...	2·8	1·8	...	...	1·6	0·8	...	...	...	...	...	...
	8. 7 30	45·0	7·8	8·0	10·0	9·0	5·4	3·0	1·8	6·0	3·0	...	...	5·2	6·2	...	...	4·8	...	...	1·2	0·2	...	...	...	...	...	...
	15. 15 30	46·5	7·3	6·5	6·0	7·3	5·9	2·1	3·2	4·3	2·5	6·0	...	...	...	...	4·7	3·2	...	...	0·5	−0·3	...	...	...	...	...	...
	17. 4 0	46·0	7·0	7·0	7·9	6·0	6·5	1·0	1·2	4·2	3·2	7·9	3·0	6·0	5·8	6·0	4·2	4·0	...	...	−0·2	0·0	...	...	...	...	...	...
XXIV.	Nov. 16. 11 25	32·2	8·0	6·8	10·8	7·2	4·7	1·5	−3·2	2·4	...	...	...	...	...	...	...	...	...	0·6	0·2	...	5·2	7·2	7·2	6·2	7·2	6·0
	18. 4 30	42·5	8·3	7·3	9·5	8·5	10·5	2·9	−1·0	2·0	...	...	...	...	...	...	...	...	...	0·5	−0·3	...	4·0	5·0	3·4	5·0	4·7	4·5
	18. 5 0	41·5	8·5	7·5	8·8	9·5	7·5	2·0	−1·2	4·5	...	...	...	...	...	...	...	...	...	0·3	0·5	...	4·3	5·2	4·4	4·7	4·0	5·0
	28. 16 0	49·0	8·8	7·8	9·4	7·5	7·4	2·8	−3·7	4·0	...	...	...	...	...	...	...	...	5·5	...	2·0	1·0	...	...	...	...	...	...
	29. 4 15	46·6	8·6	8·6	9·6	9·8	7·6	3·6	0·5	3·6	...	...	...	...	...	...	...	...	...	...	2·1	1·6	...	...	...	...	...	...
	29. 5 10	45·3	8·3	7·1	8·3	6·8	7·0	2·3	−0·2	3·6	...	...	...	...	...	...	...	...	...	...	0·6	0·3	...	...	...	...	...	...
	29. 9 10	42·5	8·5	8·5	9·9	11·0	7·5	3·5	0·2	4·7	...	...	...	...	...	...	...	...	...	...	1·5	0·9	...	...	...	...	...	...
	Dec. 1. 9 5	42·3	8·1	7·3	5·3	7·2	8·3	4·3	...	1·3	...	...	...	...	...	...	...	...	...	...	...	1·1	...	...	...	...	...	...
	5. 16 15	42·7	8·0	7·7	7·7	7·7	7·3	3·7	−1·3	2·0	...	...	...	...	...	...	5·6	...	...	...	0·9	0·4	...	...	...	...	...	...
	6. 4 45	45·2	8·2	7·2	9·7	8·6	6·5	3·2	0·4	3·2	...	...	...	3·0	4·8	...	5·2	4·8	...	...	0·5	0·2	...	...	...	...	...	...
	6. 5 10	44·5	8·0	7·0	8·9	7·9	6·6	2·8	...	...	2·4	...	...	...	...	...	...	...	...	...	1·0	0·7	...	...	...	...	...	...
	8. 13 35	38·1	8·3	4·1	9·6	6·9	6·6	4·1	−2·5	2·3	2·1	...	...	...	...	...	...	...	...	...	...	2·1	...	...	...	...	...	...
	11. 3 55	42·8	8·9	7·8	9·7	10·2	8·8	...	−2·7	3·3	−0·4	...	...	...	...	...	...	...	...	...	1·0	0·8	...	...	...	...	...	...
	17. 13 35	38·6	8·4	6·3	6·6	6·4	4·6	2·0	−2·2	−0·4	2·9	...	...	...	1·6	5·1	...	...	...	...	...	1·4	...	...	...	...	...	...
XXV.	Nov. 29. 7 30	43·7	9·7	8·7	10·7	11·7	9·2	5·2	−0·3	3·7	...	...	...	...	...	...	...	...	...	...	2·5	2·2	...	...	...	...	...	...
	29. 13 45	41·2	9·5	8·2	9·0	6·7	8·2	3·7	−0·8	3·0	...	...	...	...	...	...	...	...	...	...	2·0	2·0	...	...	...	...	...	...
	Dec. 8. 5 0	46·3	9·3	9·3	13·5	13·3	7·3	3·3	1·3	4·3	1·5	...	...	...	...	...	...	5·3	...	...	1·5	1·1	...	...	...	...	...	...
	8. 12 15	40·5	9·3	6·0	9·5	8·7	7·0	3·3	−0·5	2·5	1·3	...	...	...	...	...	...	4·3	...	...	...	2·5	...	...	...	...	...	...
	11. 4 30	41·2	9·7	8·7	10·7	11·2	9·2	2·4	−2·8	0·7	−1·6	5·2	4·2	4·2	4·2	8·2	5·4	5·0	...	...	1·0	0·7	...	...	...	...	...	...
	11. 5 30	40·1	9·3	9·1	9·1	9·3	9·1	3·3	−2·2	0·4	−1·1	...	...	...	...	...	5·5	3·5	...	...	0·6	0·4	...	...	...	...	...	...
XXVI.	Nov. 16. 7 10	38·5	10·8	10·8	18·5	13·5	11·5	7·0	−0·5	3·5	...	...	...	...	...	...	...	...	6·5	5·4	4·7	...	11·0	13·5	12·3	13·7	12·5	12·7
	18. 4 35	42·5	10·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·5	11·5	10·6	11·6	12·0	11·0
	28. 18 50	45·5	10·5	9·3	10·5	7·7	8·7	3·8	1·5	6·5	...	...	...	...	...	...	...	...	...	...	1·9	1·2	...	...	...	...	...	...
	29. 12 30	41·5	10·3	7·6	9·9	10·0	9·5	3·5	−0·5	2·6	...	...	...	...	...	...	...	...	...	...	1·5	1·0	...	...	...	...	...	...
	29. 15 0	37·5	10·5	7·5	14·0	13·0	10·0	3·3	−3·5	2·0	...	...	...	...	...	...	...	...	...	...	1·5	1·2	...	...	...	...	...	...
	Dec. 8. 4 10	48·0	10·0	10·7	12·2	11·8	...	...	1·8	...	...	...	...	...	...	...	8·0	...	...	...	1·7	2·0	...	...	...	...	...	...
	8. 9 30	43·5	10·3	8·5	13·3	12·2	7·1	3·2	0·8	6·5	1·7	...	...	7·7	9·2	...	7·5	4·9	...	...	1·9	1·5	...	...	...	...	...	...
XXVII.	Nov. 16. 5 10	40·5	12·5	9·5	15·3	12·0	8·6	5·5	0·5	2·5	...	...	...	...	...	...	...	...	...	2·5	2·0	...	11·5	11·0	10·7	10·7	10·5	11·7
	16. 7 45	36·2	12·7	11·2	17·2	12·7	9·2	5·0	−1·3	1·7	...	...	...	...	...	...	...	...	...	3·1	2·4	...	10·2	11·5	10·2	10·7	9·0	11·2
	16. 8 45	34·8	12·8	9·8	16·8	12·0	8·8	5·6	−2·2	1·8	...	...	...	...	...	...	...	...	...	3·3	2·8	...	10·3	11·3	11·8	14·3	12·8	13·6
	Dec. 8. 4 30	47·6	12·1	11·4	13·6	11·6	8·6	4·3	2·6	2·6	...	...	...	6·6	8·6	8·6	...	...	...	...	0·9	1·6	...	...	...	...	...	...
XXVIII.	Nov. 16. 9 40	35·5	13·5	12·0	17·5	12·0	10·3	5·7	−1·0	2·5	...	...	...	...	...	...	...	...	...	4·3	3·7	...	13·7	13·5	14·0	15·0	14·5	14·7

Nov. 29, 13h 45m; there is a small quantity of cloud over the zenith. Dec. 8, 5h 0m; there are a few light clouds scattered about the sky. Dec. 8, 12h 15m; dew is abundant.

Table (Continued).

Excess of the reading of the thermometer in air above that placed																										Clouds.			Wind.		
On lambs' wool on grass.			On copper on grass.	On lead on grass.	On iron on grass.	On zinc on grass.			On tin.			On tin-foil.	On pantile.	On slate.	On stone.			On brick.	On glass on grass.	On glass one inch high.	On unwrought white cotton wool on grass.	On the raised board.	One-fourth of an inch above water.	On coarse flax on grass.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.	Haze, fog, mist, or vapour.
Yellow.	Crimson.	Scarlet.				Thick.	Of moderate thickness.	Thin.	White on grass.	White one inch high.	Blackened on grass.				Firestone.	Purbeck.	Portland.													
4·8	4·0	4·8	...	4·8	...	...	...	...	...	...	...	...	3·8	4·4	...	...	...	...	...	...	...	4·8	...	2·6	Clear					
...	...	...	4·3	3·0	4·7	...	...	...	...	...	...	...	3·7	4·3	2·7	...	...	2·7	...	...	...	...	2·5	...	.....	4	...	w.	L.	Vap.
...	...	...	4·5	2·5	4·7	...	3·9	...	...	4·2	5·7	...	4·9	4·5	5·1	...	...	2·9	...	...	...	...	...	...	.....	5				
...	...	...	...	5·3	5·6	4·0	...	...	...	4·6	6·7	...	5·8	6·3	5·3	...	...	4·6	...	5·8	...	...	...	...	.....	3				
...	...	...	5·0	2·1	3·3	3·0	3·3	3·6	4·3	3·3	5·4	...	2·9	3·3	3·4	...	...	1·6	6·5	4·3	...	...	2·0	...	Light clouds	...	...	...	...	Haze.
...	...	...	5·3	3·3	3·7	4·0	4·5	4·7	4·0	2·9	5·5	...	3·7	3·3	3·5	...	...	2·4	5·5	4·0	...	...	2·3	...	Light clouds	...	...	...	...	Haze.
...	...	...	5·8	4·3	4·8	5·0	5·2	5·3	5·3	5·0	6·0	...	4·6	4·6	4·0	...	...	3·6	6·3	4·6	...	...	3·0	...	Clear	...	...	c.		
...	...	...	...	4·0	...	4·0	4·0	...	5·0	...	5·8	...	...	4·2	...	...	...	...	4·2	2·8	...	...	...	...	Clear	...	...	c.		
...	...	...	4·8	5·3	4·6	5·6	4·6	...	5·0	4·8	5·6	...	...	4·8	4·6	...	...	3·3	5·6	4·8	...	...	...	...	Clear	...	...	c.		
...	...	...	7·8	7·0	6·2	...	7·0	7·0	6·0	6·0	8·0	...	6·0	7·0	5·0	...	...	5·4	7·5	6·0	...	...	...	...	Clear	...	...	c.		
...	...	...	...	3·2	...	...	4·5	...	...	...	5·5	...	...	...	3·3	...	...	...	5·3	3·5	...	...	...	...	Clear	...	...	c.		
...	...	...	6·2	1·2	4·5	5·5	5·5	5·5	4·5	4·5	4·5	...	...	...	2·2	3·2	3·2	...	6·0	4·0	...	...	4·0	...	Clear	...	...	c.		
2·2	8·2	5·2	...	5·4	...	...	...	...	...	...	...	...	1·8	3·7	...	...	...	...	...	...	10·7	...	...	8·0	.....	8				
5·5	4·0	6·3	...	6·0	...	...	...	...	...	...	...	...	6·0	4·5	...	...	...	...	...	...	...	...	...	...	Clear	...	...	...	2	
5·6	4·3	5·0	...	4·3	...	...	...	...	...	...	...	...	4·3	4·0	...	...	...	...	...	...	...	2·7	...	3·7	Light clouds	...	...	...	2	
...	...	...	7·5	6·7	5·7	...	...	...	5·8	...	...	...	2·9	6·0	4·2	...	...	4·0	...	...	...	...	4·0							
...	...	...	7·4	5·6	6·1	...	...	4·8	5·6	...	7·6	...	6·1	5·8	4·8	...	...	4·6	...	...	...	...	...	...	.....	4				
...	...	...	4·6	4·3	4·8	3·7	...	...	6·3	...	6·3	...	4·5	5·1	3·7	...	...	3·7	...	1·0	...	...	...	...	.....	7				
...	...	...	6·5	4·5	3·8	...	...	4·0	5·5	...	8·0	...	5·5	4·7	5·5	...	...	4·7	...	...	...	...	...	...	.....	3				
...	...	...	4·8	3·7	...	...	4·5	...	4·3	...	6·1	...	4·3	6·3	...	...	...	...	5·8	4·8	...	...	...	...	.....	5				
...	...	...	7·1	6·9	5·7	6·9	6·7	7·2	6·9	5·6	6·9	...	4·9	5·9	...	...	...	...	6·9	...	...	...	...	...	Clear					
...	...	...	5·9	5·2	5·0	5·9	5·7	5·9	5·6	...	6·2	...	4·6	4·7	3·7	...	...	3·4	6·4	5·3	...	...	2·9	...	Clear					
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear					
...	...	...	...	5·5	...	7·1	8·1	...	...	5·1	7·9	...	6·5	4·9	...	...	...	...	6·3	4·1	...	...	2·1							
...	...	...	6·8	4·8	5·8	6·8	6·8	7·0	5·7	...	8·6	...	...	...	1·8	...	...	...	8·0											
...	...	...	4·1	4·6	...	5·2	6·0	...	4·4	...	5·1	...	...	...	...	...	1·5													
...	...	...	7·5	5·9	6·4	...	...	...	...	6·7	8·7	...	6·7	6·9	4·7	...	...	5·2	...	...	...	...	...	...	Clear	...	...	...	1	
...	...	...	10·3	8·2	7·0	6·0	6·0	5·7	6·3	6·0	6·8	...	6·7	7·4	6·4	...	...	5·7	9·0	8·0	...	...	5·2	...	.....	...	...	...	...	Vap.
...	...	...	9·5	8·3	6·3	9·3	9·1	...	7·1	7·3	9·3	...	6·1	6·3	3·5	...	...	...	11·3	5·7	...	...	4·3	...	.....	...	...	...	...	H. V.
...	...	...	...	9·0	6·0	...	...	7·5	7·3	...	6·5	...	...	7·8	5·0	...	...	...	8·2	6·0	...	...	3·5	...	.....	...	...	...	...	H. V.
...	...	...	8·7	6·2	5·7	7·2	7·2	7·2	5·2	6·2	9·2	...	...	...	2·2	2·4	2·7	3·2	8·4	6·4	...	...	3·4	...	Nearly clear	...	...	...	...	Mist.
...	...	...	6·1	6·0	5·4	6·1	6·0	6·4	5·1	5·1	7·1	...	...	...	2·5	2·9	3·1	3·3	7·1	5·1	...	...	2·3	...	.....	...	...	...	...	Mist.
2·5	11·0	11·7	...	...	...	...	...	...	...	...	...	...	7·0	8·7	...	...	...	...	...	...	16·4	...	...	11·8	Clear	...	...	...	...	Fog.
1·3	11·3	11·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear					
...	...	...	9·3	7·5	6·5	...	...	...	6·5	...	...	...	4·3	5·5	5·5	...	...	3·3	...	...	...	4·5	...	...	.....	1				
...	...	...	8·7	9·5	6·5	5·0	4·3	6·0	5·0	5·1	7·3	...	8·0	6·5	6·0	...	...	5·5	8·7	7·2	...	5·0	...	...	A few clouds					
...	...	...	7·5	6·3	5·5	5·8	5·5	5·3	6·5	4·5	7·5	...	5·5	5·5	4·7	...	...	5·0	7·5	5·5	...	3·5	...	...	A few clouds	...	...	...	...	Vap.
...	...	...	8·0	7·5	6·4	...	8·0	8·5	6·7	...	8·0	...	6·0	6·0	...	...	...	4·0	8·2	...	...	...	...	...	Light clouds	...	...	...	...	H. V.
...	...	...	9·1	8·3	7·3	8·3	8·5	8·5	8·5	9·5	10·3	...	7·0	7·5	6·0	...	...	5·0	8·5	...	...	4·5	...	...	Light clouds	...	...	...	...	H. V.
1·5	10·0	11·5	...	6·5	...	...	...	...	...	...	...	...	5·7	7·3	...	...	...	...	...	...	8·7	...	...	11·0	Clear	1	...	c.		
2·0	10·2	12·2	...	8·7	...	...	...	...	...	...	...	...	4·4	7·2	...	...	...	...	...	...	16·2	...	...	12·0	Clear	...	...	c.	...	Fog.
2·8	12·3	12·8	...	8·6	...	...	...	...	...	...	...	...	4·3	7·8	...	...	...	...	...	...	14·8	...	...	12·0	Clear					
...	...	...	8·6	7·3	6·8	9·1	8·1	9·1	8·1	8·4	9·0	...	6·1	5·6	5·6	...	...	4·8	10·4	7·4	...	...	...	...	Clear	...	...	c.		
5·9	14·3	13·7	...	9·9	...	...	...	...	...	...	...	...	5·0	9·3	...	...	...	...	...	...	16·7	...	...	12·0	Clear					

In addition to the tabulated experiments, a variety of others were always in progress. I may mention the results of a few of these.

I placed a large sheet of pasteboard vertically on the grass plat, and laid a thermometer close to its lower edge on each side of it; the readings of both these thermometers thus placed were found to be identical and intermediate to that placed in air at the height of four feet and protected from the effects of radiation, and that placed on grass fully exposed to the sky; the same relation was found to exist in what azimuth soever the board was placed.

I then placed the pasteboard at an angle of 45° nearly with the horizon, and laid the thermometers as before. In this situation their readings were found to be intermediate as before, but that which was exposed to three-fourths of the sky, read most nearly to that on the grass fully exposed to the sky, and the one which was exposed to one-fourth part of the sky only, read most nearly to that in air. The amount of these differences of readings was as nearly as could be determined exactly proportional to the amount of the exposed sky.

Hence, as a general fact it may be considered, that whatever diminishes the view of the sky as seen from an exposed body, causes its temperature to decrease less than it would if the exposure to the sky be complete.

Various experiments were made to ascertain the effect of covering plants at night by matting, or other thin substances; and it was always found that when the protecting substances touched the plant, much heat was conducted away from it, and such plant was at a lower temperature than when the substance was merely interposed between it and the sky; the thinnest substance thus interposed, at any distance from the plant, was found to be effectual in preventing the loss of its heat by radiation. It was found, however, that when a plant was thus itself protected, but yet was exposed to any body which was exposed to the sky, more heat radiated from the former to the latter, than from the exposed body to the plant, and thus it lost some heat.

The several thermometers at the different distances from the earth were for some time read at short intervals during the night and day, and it was found that except after noon, the reading of the thermometer at twelve feet from the earth was very nearly identical with the true temperature of the air.

The bulb of the thermometer thus exposed to the full rays of the sun was situated nine inches west of the plank which carried it, and whose width was three inches; and the cause of its readings being about 1° too high during the afternoon, was owing to the heat reflected from the plank to it.

During the summer of 1844 and the year 1845, the reading of this thermometer was frequently examined, and found always thus to agree. Hence there is no doubt that if a thermometer be freely suspended in the air with its bulb at the height of thirteen feet above the soil, and far from any object to reflect heat to it, its readings will represent the true temperature of the air at the time, and much more truly than those of any one placed near the ground, or within a few feet of walls or buildings.

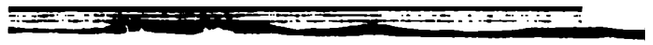
fferent substances fully exposed to the sky, arranged according to the difference of the readings of
y 1 and 1844 May.

in.								On stone.			On Lamb's wool on grass.									Clouds.			Wind.		Haze, fog, mist, or vapour.	1844. Day, hour and minute.	Number of the Tables.
High.	Blackened on grass.	On glass on grass.	On glass one inch high.	On pantile.	On slate.	On hare-skin.	On rabbit-skin.	Firestone.	Purbeck.	Portland.	Yellow.	White.	Jet black.	Crimson.	Orange.	Light blue.	Dark blue.	Green.	Scarlet.	Modification.	Amount 0–10.	High or low.	Direction.	Strength 0–6.		h m	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°								
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	10	L.	E.	L.		Feb. 21. 11 0	XXIX.
...	...	...	...	...	...	3·2	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			Apr. 25. 5 45	XXX.
3	1·3	2·6	2·1	−1·7	...	...	...	−0·2	−0·2	−0·2	...	...	...	...	...	...	...	...	...	Cumuli.....	5					Feb. 16. 3 0	XXXI.
	...	2·5	2·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	7					Mar. 6. 19 0	
	4·5	4·3	3·5	2·9	...	...	...	2·7	2·4	2·7	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	$\frac{1}{2}$		Jan. 6. 7 30	XXXII.
7	2·4	3·2	0·2	2·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	1		Feb. 1. 3 30	
	...	3·3	1·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	S.	1		Mar. 1. 11 0	
	...	5·1	4·1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			Feb. 7. 19 0	XXXIII.
2	4·9	5·3	4·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	9	H.	S.	$\frac{1}{4}$		22. 18 45	
	4·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	1	...	C.	...	Haze	28. 12 0	
	...	3·5	3·5	...	...	1·3	1·0	...	...	...	...	...	...	...	...	...	...	...	...	Thin cirrost.	10	H.				Mar. 20. 20 10	
	...	3·8	3·8																							Apr. 11. 13 0	
	...	4·2	3·2																							15. 9 0	
	...	5·7	7·3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			23. 8 55	
	5·3	5·7	4·3	...	...	...	...	3·9	4·1	...	...	...	...	...	...	...	...	...	...	Fleecy cl....	5	H.	N.	L.	Haze	Jan. 18. 19 0	XXXIV.
7	5·2	5·4	3·7	4·0	1·2	...	...	2·7	2·0	2·7	...	...	...	...	...	...	...	...	...	Fleecy cl....	3	H.	N.	L.		Feb. 1. 9 0	
4	5·4	7·5	6·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	...	...	Fog.	20. 9 10	
	6·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			22. 14 30	
3	4·6	6·8	5·3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			22. 16 0	
	...	5·3	4·3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			22. 17 30	
	5·8	2·5	0·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			28. 18 30	
2	5·8	5·1	3·9	...	...	6·9	6·9	...	...	...	5·1	4·1	4·6	3·9	6·0	4·1	5·1	5·3	3·9	Clear	...	...	C.			Apr. 1. 15 30	
	8·0	5·2	5·3	...	...	7·3	6·5	...	...	...	6·3	6·0	5·3	6·0	7·0	6·3	7·0	5·5	5·3	Clear	...	...	C.			1. 17 0	
	...	6·2	5·0	...	...	7·0	6·2	...	...	...	3·7	3·2	3·2	4·4	4·4	3·2	3·7	4·2	3·7	Clear	...	...	C.			17. 17 0	
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			25. 6 15	
	...	5·8	4·5	3·1	...	...	...	...	2·7	...	...	...	...	...	...	...	...	...	...	Scud.....	3					Jan. 6. 5 0	XXXV.
	...	5·0	4·4	3·7	...	...	...	...	4·0	...	...	...	...	...	...	...	...	...	...	Nearly cl....	3					10. 7 0	
	7·0	9·5	6·8	...	...	...	...	3·5	...	...	...	...	...	...	...	...	...	...	...	Nearly cl....	2	...	C.			22. 7 30	
	7·1	7·9	6·6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	L.		Feb. 22. 6 45	
	5·8	6·3	4·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	L.		22. 12 30	
	6·0	7·5	6·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			23. 13 0	
	...	4·2	2·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	L.		28. 17 0	
	...	6·0	5·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	2	Vap.	Mar. 12. 9 0	
	7·2	5·7	4·7	...	...	7·7	7·2	...	...	...	7·4	5·7	5·2	6·0	6·7	6·0	6·7	5·1	6·1	Clear	...	...	C.			Apr. 1. 14 30	
	...	...	3·5	...	...	6·9	6·7	...	...	...	4·2	4·2	4·2	4·7	4·2	4·7	4·4	4·5	4·3	Clear	...	...	C.			5. 17 30	
	...	6·7	5·7	...	...	11·1	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			17. 16 0	
	...	5·2	5·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A few light c.	$\frac{1}{2}$	...	E.	L.		29. 9 0	
	7·0	6·8	5·6	4·0	3·9	...	...	4·3	3·4	3·5	...	...	...	...	...	...	...	...	...	Light clouds	5	H.	N.	L.	Haze	Jan. 17. 5 0	XXXVI.
	5·7	7·9	5·1	...	...	...	...	5·3	4·0	4·6	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	$\frac{1}{2}$		30. 4 30	
	6·3	9·4	3·6	...	...	...	...	3·5	2·6	3·1	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	$\frac{1}{2}$		30. 5 30	
	7·5	5·5	5·0	3·5	...	...	...	0·5	2·0	4·2	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	L.		Feb. 1. 7 0	
	6·0	7·0	5·0	3·8	...	...	...	3·5	4·0	3·3	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	L.		16. 8 0	
	...	5·8	5·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	1		Mar. 6. 11 0	
	7·5	7·7	7·7	...	...	12·2	11·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	$\frac{1}{2}$		20. 9 0	
	6·7	7·2	6·2	...	...	11·2	12·7	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	$\frac{1}{2}$		20. 10 0	
	6·0	7·0	5·5	...	...	11·0	13·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	$\frac{1}{2}$		20. 11 0	
	7·0	7·7	6·4	...	...	10·9	11·4	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	$\frac{1}{2}$		20. 11 30	
	5·0	8·5	5·9	...	...	7·5	6·1	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			20. 18 20	
	...	7·0	7·0	...	...	6·5	6·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			Apr. 1. 18 30	
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	S.	1		2. 9 0	
	...	9·9	6·4	...	...	7·1	10·8	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			8. 13 30	
	...	10·1	7·7	...	...	8·9	9·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			8. 15 30	
	...	10·0	8·1	...	...	10·4	10·8	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			8. 17 30	
	...	7·7	6·5	...	...	7·5	7·0	...	...	...	5·0	4·7	4·7	4·5	4·8	6·5	5·3	5·0	5·2	Clear	...	...	C.			17. 15 0	
	...	5·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			17. 18 30	
	...	5·0	7·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			23. 7 25	
	...	9·5	9·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	C.			27. 7 8	

On glass on grass.	On glass one inch high.	On pantile.	On slate.	On hare-skin.	On rabbit-skin.	On stone. Firestone.	On stone. Purbeck.	On stone. Portland.	On Lamb's wool on grass. Yellow.	White.	Jet black.	Crimson.	Orange.	Light blue.	Dark blue.	Green.	Scarlet.	Clouds. Modification.	Amount 0—10.	High or low.	Wind. Direction.	Wind. Strength 0—6.	Haze, fog, mist, or vapour.	1844. Day, hour and minute.	Number of the Tables.
8·5°	5·6°	°	°	°	°	3·5°	2·8°	°	°	°	°	°	°	°	°	°	°							h m	
7·7	5·7	...	...	...	...	4·7	4·5	4·1	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...		Jan. 22. 10 30	
7·5	7·0	3·0	...	...	...	4·5	4·0	6·0	...	...	...	...	...	...	...	...	...	Clear	...	...	N.	½	Haze	26. 7 30	
7·0	5·0	3·8	...	...	...	3·5	4·0	3·3	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	L.		Feb. 1. 5 0	
7·7	6·2	6·2	...	...	...	4·4	5·4	4·7	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	L.		15. 19 15	
7·6	4·8	4·7	...	...	...	4·6	5·1	4·0	...	...	...	...	...	...	...	...	...	Clear	...	...	W.	½–½	Vap.	16. 7 0	
8·7	8·0	4·7	...	...	...	4·5	4·7	4·9	...	...	...	...	...	...	...	...	...	A thin cloud	10					16. 9 0	
8·7	7·9	...	...	9·2	9·2	...	...	...	7·5	7·9	5·5	7·2	8·2	8·2	6·7	7·7	6·6	Clear	...	...	c.			20. 5 0	
7·1	6·3	...	...	7·8	8·1	...	...	...	8·3	4·3	4·3	4·3	5·3	5·8	7·8	6·8	7·1	Clear	...	...	c.			Apr. 1. 12 30	XXXVII.
5·6	6·5	...	...	8·7	9·2	...	...	...	5·9	5·9	2·5	5·2	6·7	5·9	5·7	4·2	4·5	Clear	...	...	c.			1. 13 30	
6·9	4·1	...	...	6·9	6·9	...	...	...	...	...	...	...	...	...	...	...	...	Cirrostratus	1	...	s.	1		1. 18 0	
7·8	6·1	...	...	10·6	10·4	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			2. 7 0	
8·5	7·5	...	...	10·3	9·5	...	...	...	6·5	7·5	5·3	6·0	6·0	6·5	7·3	6·0	5·3	Clear	...	...	s.	1		3. 17 30	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	E.	1		17. 12 0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	E.	1		29. 11 0	
																								30. 7 40	
																								Feb. 13. 20 0	
9·2	7·0	...	...	...	...	5·3	5·0	4·8	...	...	...	...	...	...	...	...	...	Nearly cl....	1	...	N.	½	Haze	Jan. 26. 5 10	
7·3	4·8	4·8	...	...	...	4·3	4·6	4·3	...	...	...	...	...	...	...	...	...	.....	2	...	N.	L.	Vap.	Feb. 15. 15 0	
9·0	6·5	3·5	...	...	...	2·8	5·0	2·8	...	...	...	...	...	...	...	...	...	.....	1	...	N.	L.	Vap.	15. 17 30	
10·5	7·7	6·5	...	...	...	4·5	5·7	4·7	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			16. 4 30	
9·5	7·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			22. 9 0	
8·7	5·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Haze	Mar. 21. 8 40	
6·2	3·2	...	5·7	8·2	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	s.	¾		Apr. 2. 8 0	
5·2	4·5	...	7·5	8·8	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	s.	L.		2. 11 0	
10·3	7·5	...	7·4	8·8	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			8. 11 0	
10·4	7·4	...	7·4	7·2	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			9. 8 50	
8·8	8·8	...	10·8	9·8	...	...	...	...	6·3	7·8	5·8	8·0	7·6	8·8	7·7	7·8	7·6	Clear	...	...	c.			17. 13 0	XXXVIII.
8·2	7·2	...	10·7	10·0	...	...	...	...	6·2	6·0	6·0	6·7	6·0	7·0	6·0	6·0	5·2	Clear	...	...	c.			17. 14 0	
6·2	5·2	...	7·2	6·7	...	...	...	...	3·7	5·7	5·7	4·4	5·0	5·4	4·0	5·0	4·7	Clear	...	...	c.			17. 18 0	
8·5	8·3	...	13·3	10·1	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			18. 17 30	
...	...	...	10·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			25. 6 40	
...	...	...	10·1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			25. 17 20	
10·8	9·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			27. 9 30	
10·7	9·3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			May 1. 9 5	
8·9	7·7	...	9·5	9·2	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			1. 11 0	
11·1	9·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Jan. 22. 8 15	
10·7	8·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			22. 9 0	
9·5	6·0	3·0	...	...	...	2·5	4·5	1·5	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Feb. 15. 18 30	
11·2	9·4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear						22. 11 30	
10·3	8·4	...	...	11·4	8·9	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.		Haze	Mar. 21. 6 30	
10·1	8·3	...	...	10·5	10·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			23. 8 40	
8·5	7·5	...	...	11·5	10·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 1. 9 0	XXXIX.
9·5	7·5	...	...	11·5	8·7	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			3. 9 0	
8·1	6·9	...	...	9·3	11·9	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	s.	L.		3. 11 30	
8·4	7·1	...	...	11·3	11·1	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	s.	L.		3. 12 45	
8·3	6·8	...	...	11·4	10·4	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	s.	L.		3. 15 30	
6·7	6·5	...	...	12·6	12·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			10. 7 0	
10·5	8·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			17. 9 30	
10·8	9·8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			May 1. 7 30	
7·6	5·8	...	...	13.3	11·8	...	...	...	10·0	8·3	8·1	8·6	10·0	8·3	9·6	8·1	10·0	Clear	...	...	c.			1. 15 0	
10·8	8·5	7·0	...	...	...	5·0	5·8	5·0	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Feb. 16. 5 30	
11·9	10·4	...	...	13·9	12·9	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 1. 12 0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			10. 8 0	
12·8	7·6	...	...	8·3	10·8	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			10. 9 0	
10·3	10·3	...	...	10·5	9·5	...	...	...	9·3	9·3	10·3	8·3	8·0	10·0	8·7	8·3	9·0	A thin cloud	...	...	w.	L.		18. 9 0	XL.
...	...	...	...	12·0	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			25. 11 30	
...	...	...	...	12·3	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			25. 16 30	
9·0	9·0	...	...	12·7	11·2	...	...	...	9·7	9·4	9·2	9·2	9·7	10·7	11·7	7·2	11·7	Clear	...	...	c.			May 1. 15 0	
10·5	9·7	...	...	13·2	12·7	...	...	...	11·2	10·2	8·7	10·7	9·7	11·5	9·2	9·5	9·2	Clear	...	...	c.			1. 17 0	
12·0	9·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			13. 19 0	

s, at an angle of about 60°; none were in the plane of the leaf continued; on the surface of the leaf there were spikes one-sixteenth of an inch in
ree from frost; the cruciform end of each branch was very rich with spikes. Broom: this shrub was richly encrusted with spikes all around each
pearance. Grass: the lower part of the blade was free from frost; immediately above this the blade was just covered with white particles, which
ly horizontal, and in the plane of the blade. Wooden palings: at all points and angles there were clusters of spikes half an inch in length. Glass
at the edges. Wood on grass was free from hoar-frost; wood raised from the ground was covered with white particles, and many spikes in the
as free from hoar-frost.

On tin.		On bare-skin.	On rabbit-skin.	On stone.			On Lamb's wool on grass.									Clouds.			Wind.		Haze, fog, mist, or vapour.	1844. Day, hour and minute.	Number of the Tables.
White one inch high.	Blackened on grass.			Firestone.	Purbeck.	Portland.	Yellow.	White.	Jet black.	Crimson.	Orange.	Light blue.	Dark blue.	Green.	Scarlet.	Modification.	Amount 0—10.	High or low.	Direction.	Strength 0—6.			
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°							h m	
7·9	9·6	13·6	12·9	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.	...	Haze	Mar. 23. 7 45	XLI.
...	...	13·1	16·1	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 3. 7 0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			6. 7 25	
...	...	15·3	13·9	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			9. 7 50	
...	...	11·5	11·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			17. 11 0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			18. 11 5	
...	...	13·0	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 14 40	
...	...	15·5	15·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 24. 9 30	XLII.
...	...	15·0	15·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 10 0	
...	...	15·0	15·0	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 10 30	
...	...	16·1	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 12 40	
...	...	16·3	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 13 40	
...	...	14·3	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			25. 15 40	
10·7	...	13·3	13·2	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 1. 11 0	XLIII.
...	...	14·3	11·7	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			8. 9 0	
...	...	11·8	10·6	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			9. 7 30	
...	...	14·5	14·5	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 9 0	
...	...	14·7	14·7	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 11 0	
...	...	15·1	15·1	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 11 30	
...	...	15·9	15·7	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			24. 12 0	
...	13·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			Apr. 8. 7 20	XLIV.
...	...	16·4	...	...	...	...	...	...	...	...	...	...	...	...	...	Clear	...	...	c.			8. 8 0	



From the preceding tables we learn the following particulars:—Tables I. to VI., XVII. to XX., and XXIX. to XXXII. contain the results of observations when the excess of air-temperature above that of long grass was less than 5°; such observations having been taken at times when the sky was wholly covered with cirro-stratus cloud, after having been cloudless, during which state a series of observations had been taken. By examining the last column of these Tables, it will be seen that when the excess of air-temperature above that of long grass has amounted to 4° or 5°, the clouds have been noted as being high, and when the excess was less than 3°, they have been mentioned as being low, or no mention has been made as to their height. Tables VII. to X., XXI. to XXIV., and XXXIII. to XXXVI. contain the results of observations at times when the excess amounted to 5°, 6°, 7°, or 8°; and from the last columns in those tables, it appears that at such times the sky was frequently cloudy, and when wholly so, that the clouds were high; that the air was in frequent motion, and at times the wind was blowing with a pressure of 4 lbs. on the square foot; that the atmosphere was occasionally thick by haze or vapour, and that dew was seldom deposited. Tables XI. to XIV., XXV. to XXVII., XXXVII. to XL. contain the results of the observations at times when the excess was 9°, 11°, or 12°; and at those times the sky has been generally clear, the air calm, and the atmosphere frequently hazy, misty, or vapour or fog was prevalent. Dew was also frequently deposited; in two cases contained in Tables XI. and XXXVII. occurring 1843, Nov. $12^d\ 13^h\ 5^m$, and in 1844, Feb. $20^d\ 5^h$, the sky was wholly covered by high and thin clouds. Tables XV. and XVI., XXVIII., XLI. and XLII., exhibit the results when the excess was 13° and 14°, and at those times the sky was generally clear, and the air was calm; haze and vapour were occasionally prevalent. Tables XLIII. and XLIV. contain the results when the air-temperature exceeded that of long grass by quantities varying from 15° to 19°; and by examining the last column of these Tables, it appears that at those times the sky was cloudless and bright, the atmosphere was clear without haze, mist or vapour, and a perfect calm prevailed.

From the above particulars it appears that at times when the sky was entirely covered with low cirrostratus clouds, the readings of a thermometer placed on long grass was the same as that in the air; that with the same clouds at a moderate elevation, the reading of the thermometer in air has exceeded that on long grass by 3°; and on those clouds being high, this excess has amounted frequently to 5°; and if other clouds than cirrostratus covered the whole sky this excess has been as large as 10°. At times when the sky has been free from clouds but not bright, haze and vapour being prevalent, the above excess has amounted to 10°, 11°, or 12°; and at times when the sky has been both bright and clear, with the air calm, no mist, haze, vapour or fog being prevalent, this difference has frequently amounted to 14°, less frequently to 19°, and sometimes to 20°.

In Tables XLII. to XLIV. are exhibited the great excess of the reading of a thermometer in air above those of thermometers placed on substances whose power for

conducting heat was bad, such as raw wool, flax, hare-skin and rabbit-skin, and contrary to expectation, even on metals, whose power for conducting heat is good.

In Table XLIV. the reading of a thermometer on raw wool was 25° less, whilst another placed at 8 feet from the ground and fully exposed to the sky, was 3°·5 greater than that in air at the height of 4 feet and proteeted from radiation, and thus a difference of 28°·5 existed between the readings of two thermometers, the one placed on raw wool, and the other in air at the height of 8 feet. This difference was the greatest that I have ever seen, and it occurred in 1844, on April 8^{d}, at 8^{h}.

The general agreement in the relative radiating powers of the different substances on different nights, and many other particulars, will be best seen by consulting Tables I. to XLIV.

I shall now proceed to explain the formation of the following table of the mean results derived from all the observations.

The mean of the numbers was taken in every group of results contained in Tables I. to XLV., for every different substance or different position of the thermometer in each period of observation, thus forming three large tables; from these a fourth table was formed by combining the mean results for every substance, according to the number of observations from which each had been deduced, omitting, however, all those which had been taken when the excess of air-temperature above that of long grass temperature was less than 2°*. From the numbers in this last table the next table was formed.

The last column but two in the following table contains the mean excess of the reading of the thermometer in air above those placed as stated in the first column, derived from all the observations made on each substance, &c. These numbers are smaller than they would have been had the observations been made in a wide and open plain (see introductory remarks), and also if the thermometer in the air had been perfectly protected from the effects of radiation (see remarks following Table XLV.). The numbers in the last column but one represent the relative radiating power of the several substances, that of long grass being considered as 1000. It is probable that these numbers are very accurate, for had the results in the preceding columns been larger than they are, they would have been relatively so, consequently the numbers in this column would not have been affected.

In most cases the experiments have been sufficiently numerous to give results worthy of entire confidence, the numbers in this column having been deduced from upwards of 10,000 experiments.

* These four Tables are in MSS. and placed with the series of observations.

Table XLV.

The mean excess of the reading of a thermometer placed in air at the height of four feet above the soil and protected from the effects of radiation, above those of thermometers placed on different substances, or in different situations, fully exposed to the sky.

Situation of the thermometer, its bulb, or the substance under which it was placed, being fully exposed to the sky.	Whole number of comparisons.	Whole sum of the excesses of the readings of the thermometer in air at the height of four feet, above those placed as stated in the first column.	Mean excess of the reading of the thermometer in air.	Relative excess, that of long grass being represented by 1000, or comparative radiating power.	Remarks.
On long grass	479	4017·7	8·39	1000	
On short grass	473	3454·7	7·30	870	
One inch below the surface of ground under grass	273	− 476·1	− 1·75	− 209	
On surface of ground under long grass	156	85·0	0·55	66	
On surface of ground under short grass	259	437·3	1·69	200	
On long grass covered by white raw wool	66	11·9	0·18	22	
On long grass covered by flax	61	20·4	0·35	42	
On long grass covered by white tin	35	119·3	3·41	406	
On long grass covered by white tin one inch high	42	126·3	3·00	357	
On long grass covered by blackened tin	28	131·9	4·71	561	
On long grass covered by lead	10	46·7	4·67	556	These observations were generally simultaneous.
On long grass covered by lead six inches high	13	40·1	3·08	367	
On long grass covered by glass	127	727·9	6·01	716	These observations were generally simultaneous.
On long grass covered by glass one inch high	128	557·5	3·35	399	
On long grass covered by hare-skin	18	13·6	0·75	89	These observations were simultaneous.
On long grass covered by rabbit-skin	17	10·1	0·60	72	
One inch high above the top of grass (in air)	226	1272·9	5·63	671	These factors, multiplied into the mean radiating power of any substance, will show the cooling effect of that substance upon the air, at that distance above it corresponding to the factor used.
Two inches high above the top of grass (in air)	9	43·0	4·78	570	
Three inches high above the top of grass (in air)	89	336·1	4·00	477	
Six inches high above the top of grass (in air)	165	394·1	2·37	282	
One foot high above the top of grass (in air)	212	229·4	1·08	129	
Two feet high above the top of grass (in air)	199	143·3	0·72	86	
Four feet high above the top of grass (in air)	87	50·3	0·58	69	
Six feet high above the top of grass (in air)	18	7·9	0·44	52	
Eight feet high above the top of grass (in air)	96	13·4	0·14	17	
Ten feet high above the top of grass (in air)	9	80·0	0·89		See simultaneous observations at 8 feet and 10 feet.
Twelve feet high above the top of grass (in air)	77	9·0	0·12	14	
On black-lead in powder on the raised board	138	808·1	5·85	697	
On charcoal in powder on the raised board	153	996·2	6·51	776	
On whiting in powder on the raised board	67	465·5	6·94	827	
On chalk in powder on the raised board	21	142·1	7·05	840	
On lamp-black in powder on the raised board	14	113·0	8·06	961	
On unwrought white cotton wool on grass	228	2074·6	9·10	1085	See simultaneous observations.
On unwrought white cotton wool on the raised board	15	127·7	8·52		
On white raw wool on grass	357	3655·1	10·24	1222	
On flax on grass	461	4563·6	9·90	1186	See simultaneous observations.
On flax on the raised board	17	76·3	6·94		
On yellow cotton, jeweller's wool, on grass	13	84·1	6·46	770	None of these observations were simultaneous.
On yellow cotton, jeweller's wool, on the raised board	56	472·0	8·43	1005	
On blue cotton, jeweller's wool, on grass	12	84·6	7·05	840	None of these observations were simultaneous.
On blue cotton, jeweller's wool, on the raised board	55	460·3	8·37	997	
On white wadding on grass	27	223·1	8·27	986	
On black wadding on grass	20	166·6	8·33	993	
On flannel on grass	29	212·1	7·31	871	None of these observations were simultaneous.
On flannel on raised board	55	408·7	7·43	886	
On raw silk on grass	32	254·0	7·84	934	None of these observations were simultaneous.
On raw silk on the raised board	50	464·3	9·29	1107	
On silk from the cocoon	24	208·1	8·67	1034	
On jet black lambs' wool	33	205·4	6·22	741	These observations were always simultaneous.
On white lambs' wool	33	227·5	6·89	821	
On green lambs' wool	33	220·2	6·76	806	
On light blue lambs' wool	33	242·6	7·35	876	
On dark blue lambs' wool	33	230·2	6·98	832	

The observations in air at the height of ten feet above grass, were made on one night only, viz. on 1844 April 24, and the readings were between those of eight feet and twelve feet.

No certain difference appeared from many simultaneous observations of fine and coarse flax, and consequently their results have been combined in the formation of the final values for flax.

TABLE (Continued).

Situation of the thermometer, its bulb, or the substance under which it was placed, being fully exposed to the sky.	Whole number of comparisons.	Whole sum of the excesses of the readings of the thermometer in air at the height of 4 feet, above those placed as stated in the first column.	Mean excess of the reading of the thermometer in air.	Relative excess, that of long grass being represented by 1000, or comparative radiating power.	Remarks.
On orange lambs' wool	33	233·3	7·07	844	These observations were always simultaneous.
On yellow lambs' wool	33	239·5	7·26	855	
On red lambs' wool	33	223·3	6·77	807	
On crimson lambs' wool	33	225·3	6·83	814	
On garden mould	151	598·5	3·96	472	These observations were generally simultaneous.
On gravel	149	361·4	2·42	288	
On river sand	157	599·0	3·81	454	See simultaneous observations.
On river sand on the raised board	25	127·6	5·10		
On tinfoil	33	129·8	3·94	470	
On lead	224	1421·7	6·35	757	See simultaneous observations.
On lead six inches high	13	53·2	4·10		
On lead one foot high	48	261·3	5·44		
On lead three feet high	2	10·5	5·25		
On copper	172	1210·5	7·04	839	
On iron	161	868·2	5·39	642	See simultaneous observations.
On zinc	213	1217·9	5·71	681	
On zinc six inches high	29	175·2	6·04		
On zinc one foot high	6	29·4	4·90		
On zinc three feet high	.6	27·0	4·50		
On zinc four feet high	4	13·2	3·30		
On white tin	112	616·6	5·51	657	
On white tin one inch high	75	378·0	5·04	601	Generally simultaneous observations.
On blackened tin	104	672·2	6·46	770	
In focus of metallic parabolic reflector	464	3340·7	7·20	858	
On the raised board	50	323·4	6·49	773	
On saw-dust in a box on the raised board	37	189·3	5·12	610	
Nine inches above wood and protected from lateral wind	394	1236·8	3·11	371	
On brick	46	143·5	3·12	372	
On pantile	111	437·2	3·94	470	
On slate	100	481·1	4·81	573	
On glass	163	1182·3	7·25	864	These observations were generally simultaneous, and with them the observation of grass under the glass.
On glass one inch high	156	954·1	6·11	728	
One quarter of an inch above water	83	225·7	2·72	324	
On paper on the raised board	8	41·2	5·15	614	
On hare-skin	70	773·1	11·04	1316	
On rabbit-skin	59	613·2	10·40	1240	See simultaneous observations.
On stone	154	503·3	3·27	390	
Number of observations of the thermometer in air, and its mean reading	487		43·7		

No certain difference was found from many simultaneous experiments on lead less than the twentieth of an inch in thickness, and lead a quarter of an inch in thickness; the observations are everywhere used as lead, independently of its thickness. The same remark applies to the three different thicknesses of zinc, and to the three different stones used; and their results have been combined as one result for "zinc," and as one result for "stones" in the final result.

Some of the particulars which we may learn from the preceding table are the following.

The first results contained in it are those relating to grass, whose radiating power appears to be such, that the reading of a thermometer when placed on it when long, is less than when it is placed on short by 1°·1; the next result relating to grass is that of the temperature on the surface of the soil under it, which is such that the reading of a thermometer under long, exceeds that under short by 1°·1; being exactly the same amount in excess under as it was in defect on the top; and hence the cause of the difference of the readings on the top of long and short grass arises solely from the greater quantity of heat conducted to the surface of the latter from

the soil, over that conducted to the surface of the former, and not from the greater quantity of heat radiated into space from the long, over that radiated from the short; such being the case, it was to be expected that the readings of a thermometer would vary with every variation of the length of grass upon which it was placed, and such was found to be the case.

In fact, the readings of thermometers placed on grass were found to differ with every variation of length, fineness and closeness of its blades. My experiments have been made on that differing only in the length of its blades, and the differences arising from this cause were found to vary with every variation of the excess of the temperature of the air over that of long grass. The following are the mean results of experiments in this respect:—

When the excess of air-temperature at the height of 4 feet above that of long grass was	between 3° and 7°	the reading of the thermometer on short grass was higher than that on long grass by	0°·8 from 125 comparisons.
	between 7° and 10°		1°·3 from 231 comparisons.
	between 10° and 19°		1°·9 from 86 comparisons.

These differences were found to correspond to a mean temperature of the air of 44°, and that of long grass of 36°, or generally to all temperatures above 30°; but when the reading of long grass declined below 30°, that of short grass was found not to decline nearly so rapidly: investigating the temperatures at readings below 30°, the following are the mean results:—

That when the reading on long grass was between	it exceeded that on short grass by ...	Comparisons.
25° and 30°	2°·0 from 10°	
20 and 25	2·4 from 31	
15 and 20	3·3 from 19	
10 and 15	4·8 from 14	
5 and 10	6·4 from 9	
0 and 5	9·4 from 2	

From another investigation, it appeared that these differences were connected with the difference between the readings of the thermometer in air and that on long grass as follows:—

When the reading of the thermometer on long grass was	at and above 30°	the excess of the reading of the thermometer on short grass was	one-eighth part,	of the excess of the reading of the thermometer in air at 4 feet high, above that on long grass.
	at 20°		one-fourth part,	
	at 10°		one-half,	
	at 0°		the whole,	

Hence it appears that at the reading of 0° of the thermometer on long grass, the reading of a thermometer on short grass is as much higher than 0°, as the reading of the thermometer in air at the height of 4 feet is higher than 0°; or that the readings on short grass and that in air are alike, and therefore that the heat conducted from the earth equals in amount the heat lost by radiation; and that for readings on long grass increasing from 0° in an arithmetical progression with a common difference of 10°, the difference between the readings on long and on short grass becomes less in geometrical progression with a common ratio of one-half; till attaining a reading of 30° the difference equals the fourth term of the series, and this difference continues very nearly constant till 60°, above which temperature I have had but few experiments. If we call the excess of air-temperature above that of long grass temperature by *e*, then the excess of the readings on short grass above those on long grass at

0°, 10°, 20° and at 30°, and above 30°, will be respectively e, $\frac{1}{2}e$, $\left(\frac{1}{2}\right)^2 e$, $\left(\frac{1}{2}\right)^3 e$; and for any intermediate reading the difference can be easily calculated from these terms. The very singular and unexpected facts now detailed, merit attention and suggest the necessity of carefully noting the position of a thermometer in any investigation in which such instrument is needed, as indeed do all the experiments that I have made, though not in so marked a manner as does this. I now proceed to the results of those experiments in which grass was covered by different substances, which are as follows:—

The covering of long grass by	caused the thermometer to read higher than one placed on uncovered grass by	the whole	of the difference between the thermometer in air at the height of 4 feet and that on long grass	or in its mean, caused the covered grass to be warmer by.....
raw wool, flax, hare-skin or rabbit-skin	... „ ...	five-eighths	... „ ...	... „ ... 8°·0
a sheet of white tin	... „ ...	five-eighths	... „ ...	... „ ... 5·0
a sheet of white tin one inch high ...	... „ ...	five-eighths	... „ ...	... „ ... 5·4
a sheet of blackened tin	... „ ...	three-eighths	... „ ...	... „ ... 3·6
a sheet of lead..... ...	... „ ...	three-eighths	... „ ...	... „ ... 3·6
a sheet of lead 6 inches high	... „ ...	five-eighths	... „ ...	... „ ... 5·4
a sheet of colourless glass.....	... „ ...	one-fourth ...	... „ ...	... „ ... 2·4
a sheet of colourless glass 1 inch high	... „ ...	five-eighths	... „ ...	... „ ... 5·0

The following are some of the particulars that we may collect from these results. The filamentous substances and skins did not allow any heat to escape from the grass they covered, thus proving them to be very bad conductors of heat. The raising any substance above the grass caused the thermometer reading to increase, although in this case it must have been exposed to a portion of the sky: this in the case of tin was a small quantity; in the cases of lead and of glass the quantity was large, with the former amounting to 1°·7, and with the latter to 2°·7 in their means. The amount of heat transmitted through a colourless medium, as glass, is remarkable, the mean amount of radiation from grass thus covered being less by only one-fourth part of that of uncovered grass.

The next investigation connected with grass was that of placing thermometers at different distances from it, with the view of determining the cooling effect of a body, as cooled by radiation, upon the air in contact with it; the results of these experiments as contained in the table, will probably be more clearly seen by arranging the numbers on the supposition that the reading of a thermometer on long grass was 0°, and combining with them those of 1 inch below and on the surface of the soil as follows:—

At one inch below the surface of the soil the mean reading would be . . .	10°·24
On the surface of the soil under long grass the mean reading would be . .	7·84
On long grass fully exposed to the sky the mean reading would be	0·00
One inch above long grass fully exposed to the sky the mean reading would be	2·76
Two inches above long grass fully exposed to the sky the mean reading would be	3·61

Three inches above long grass fully exposed to the sky the mean reading would be 4°·39
Six inches above long grass fully exposed to the sky the mean reading would be 6·02
One foot above long grass fully exposed to the sky the mean reading would be 7·31
Two feet above long grass fully exposed to the sky the mean reading would be 7·67
Four feet above long grass fully exposed to the sky the mean reading would be 7·81
Six feet above long grass fully exposed to the sky the mean reading would be 7·96
Eight feet above long grass fully exposed to the sky the mean reading would be 8·26
Twelve feet above long grass fully exposed to the sky the mean reading would be 8·27
And the one in air at the height of four feet, protected from six-tenths of the sky, would be . . . . . 8·39

The numbers in the last column of Table XLV., opposite to the respective heights above long grass, are factors deduced by considering the radiation from long grass to be represented by unity, and therefore the numbers represent the factors corresponding to the cooling effect of a body cooled by radiation upon the air at different heights above it. They may be considered to apply to all bodies whose radiating powers are known, the cooling effect of which upon the air at any particular distance above them, less than twelve feet, will be known by multiplying the mean radiating power into the factor corresponding to that distance.

The greater coldness of grass than that of the air in clear and calm weather, in places sheltered from the sun but open to a considerable portion of the sky, may continue all the day as well as night, and from many unrecorded observations, this appears to occur frequently. On September 22^{d}, 1843, this was observed to be the case; the day was fine, the sky was nearly cloudless, and the reading of the barometer was high. A thermometer on the grass was placed in the shade, and exposed to as much of the sky as possible, and the following observations were taken:—

1843. Month, day, and hour.	Reading of thermometer		Excess of reading of thermometer in air above that on grass.	Remarks.
	In air.	On the grass.		
h m				
Sept. 21. 21 30	62°·8	58°·5	4°·3	Cloudless; dew abundant.
22 15	60·0	54·3	5·7	Cloudless; dew in globules on grass.
23 20	65·5	64·0	1·5	Large clouds to the north; dew abundant.
23 50	66·5	61·5	5·0	Cloudless; dew abundant.
Sept. 22. 0 0	69·0	62·0	7·0	A few clouds to the north.
1 0	68·9	61·5	7·4	Thin clouds to the north.
1 40	68·7	59·0	9·7	Cloudless.
1 53	68·7	58·8	9·9	Cloudless.
3 30	67·0	58·4	8·6	Cloudless.
4 0	66·6	59·4	7·2	Cloudless.
4 20	66·3	58·7	7·6	Cloudless.
4 35	65·8	57·5	8·3	Cloudless.
5 0	65·2	56·8	8·4	Cloudless.

The thermometer was frequently moved so as to keep it in the shade, and on grass upon which the sun had not shone for a long time.

At noon on this day a thermometer was placed on grass upon which the sun had been shining till Sept. 21^{d}, 23^{h} 45^{m}, and the following observations were taken :—

1843. Month, day, and hour.	Reading of thermometer		Excess of reading of thermometer in air above that on grass.	Remarks.
	In air.	On the grass.		
h m				
Sept. 22. 0 0	69°·0	67°·0	2°·0	A few clouds to the north.
1 0	68·9	64·5	4·4	Thin clouds to the north.
1 40	68·7	64·0	4·7	Cloudless.
3 30	67·0	61·7	5·3	Cloudless.
4 0	66·6	61·5	5·1	Cloudless.
4 20	66·3	61·0	5·3	Cloudless.
4 35	65·8	59·7	6·1	Cloudless.
5 0	65·2	59·0	6·2	Cloudless.

During the whole of this day the temperature of the grass in the shade was several degrees below that of the air at four feet above it, and dew remained all day upon that portion of grass upon which the sun had not shone. Also the temperature of that upon which the sun had been shining soon began to decline, but it did not descend so low as that of the dew-point, which was about 58°, and therefore no dew was deposited upon it.

This day followed a long period of hot weather without rain, and the day was nearly cloudless, with the sun shining brightly.

This closes the experiments connected with grass with mercurial thermometers, and it will be seen that I have paid very much attention to them, as grass is a substance upon which many former experiments have been made, the discrepancies between which are now fully accounted for.

I may here point out one important result of the preceding experiments; viz. the amount of the corrections dependent upon the portion of clear sky to which the bulb of a thermometer is exposed, necessary to be applied to its readings to obtain from them the true temperature of the air. As a thermometer at the height of four feet, protected from six-tenths of the sky, was found to read 0°·58 higher than another at the same height fully exposed to the sky, it follows that the effect of protecting the bulb of a thermometer from the sky, whose height from the ground was four feet, was to cause the readings to increase 0°·1 for every tenth part of the sky protected: hence, if a thermometer be wholly exposed to the sky, it is necessary to increase its readings by

$$0°{\cdot}1 \times \text{number of tenths of cloudless sky ;}$$

and if the bulb be partially protected from the sky, the correction is

$$\left(10 - \left\{\begin{array}{l}\text{quantity of sky in tenths from}\\ \text{which the bulb is protected}\end{array}\right\}\right) \times 0°{\cdot}1 \times \text{number of tenths of clear sky.}$$

From this it appears that the thermometer, which throughout all the experiments has been considered to have been protected from the effects of radiation, was yet subjected to it to the amount of 0°·4 on a cloudless sky, or to 0°·4 × number of tenths of clear sky at times when the sky was partially cloudy.

If attention be paid to the placing of thermometers, so that their bulbs be in the shade, protected from rain and from the effects of radiation from walls (by placing their bulbs at least six inches from them), but in other respects freely exposed to the air, and correcting their readings by the preceding formulæ, it will ensure the obtaining the true temperature of the air from them at night. To avoid the effects of reflected heat during the day, the thermometers should be placed at a greater distance than six inches from walls, &c., and their readings corrected as before by the preceding formulæ. No simple rules have hitherto been given for placing a thermometer so that from its readings the true temperature of the air could be deduced.

The readings of thermometers placed on grass being found so variable, the unfitness of it to furnish the means of comparing the degrees of cold at night on the surface of the earth was evident. A much greater uniformity was observed in the results of experiments made with other substances, which were bad conductors of heat, and whose condition was always the same.

Of all the substances experimented upon, those on which the readings of the thermometers have been the lowest were hare-skin and rabbit-skin*; and upon the filamentous, as raw wool, flax, unwrought cotton wool, and raw silk, the readings upon all of which were more steadily less, on clear and calm nights, and exhibited a greater degree of cold, than those on grass. Among bodies of this class, raw wool exhibited a lower reading at all times than any of the rest; the circumstance of hare-skin and rabbit-skin exhibiting a lower mean in the table is accidental, experiments on these substances having been made only during the finest nights, and on which nights raw wool exhibited lower readings than they did. The next in order is flax, both fine and coarse, and in its mean it exhibits a radiating power very nearly equal to that of raw wool; but the last-mentioned substance was much more sensible on the approach of a cloud than any other substance: on those nights which were clear for many hours, raw wool obtained its lowest readings long before flax; and the readings on wool, on the approach of a cloud, increased much sooner than those on flax; and in consequence of the latter circumstance, the mean values deduced from raw wool and flax were nearly the same. In intervals of clear sky, between cloudy states of it, the difference between the readings of two thermometers, the one in air and the other on raw wool, was the greatest of any of the differences. The rapidity of the decrease of the readings on raw wool from a cloudy to a clear sky was about a degree per minute, so that a change in the readings of 15° has taken place in a quarter of an hour. The greatest difference between the temperature of a body at night on the surface of the earth, and that of air a few feet above the earth, was 28°·5; this extraordinary difference occurred in 1844, April 8^{d}, at 8^{h} (See Table XLIV.). The times

* Thus explaining the fact frequently noticed by sportsmen, that the snow upon which hares have been lying is never in the slightest degree melted.

at which other large differences took place, with their amounts, will be seen in Section II.

The next class of bodies consisted of black and white wadding, flannel, and wool of different kinds and colours. Of these, black and white wadding exhibited the lowest readings, and were nearly equal in amount; flannel was the next in order, and the various-coloured lambs' wool were the next; but the differences between those bodies with respect to their radiating powers were not large; they were all, however, inferior in their radiating powers to bodies of the first class. It will be seen in Table XLV. that the numbers opposite to flannel, yellow and blue cotton wool, when those substances were placed on the raised board, are larger than those numbers with the same substances placed upon grass; these differences most probably arose from the different quantities of heat which they received from the parts beneath, the several substances being slow conductors of heat.

The observations upon the coloured wools were too few to indicate positively the influence of colour, nevertheless they were all good and simultaneous experiments. The order of their radiating power is black the lowest, then green, white, crimson, scarlet, orange, yellow, dark blue and light blue successively, the difference between light blue and black being 1°·3. The same parcels of wool were exposed to the direct rays of the sun many times, and as nearly similarly situated as possible. The mean of fifty-eight simultaneous readings of the thermometers placed on them gave—

Black	105°
Yellow	105
Scarlet	107
Orange	109
White	110
Green	110
Crimson	110
Dark blue	110
Light blue	121

Thus black and light blue are at the extremes of the absorptive powers, and so far confirm the results obtained by the night observations, as the absorptive power of substances is proportional to their radiating power.

But as these results with respect to colours may have been affected with the particular parcels of wool I used, and different results might have been obtained had other parcels been used, I do not place much confidence in them; yet, so far as I could discover, each parcel was equal in thickness, hardness, and in fact in every respect except that of colour.

Bodies in the state of powder, placed on the raised board, formed a third class of substances. These were black-lead, charcoal, whiting, chalk, lamp-black and river-

sand. The lowest readings occurred on lamp-black; the next in order were chalk, whiting, charcoal, black-lead and sand; a quantity of the last-mentioned substance was also placed on the ground to the depth of three inches, and to an extent of nine square feet; the difference between the mean readings of thermometers placed on sand in these two positions is probably accidental, arising from the observations in the former case having been taken on very fine nights only.

Building materials formed a fourth class; these consisted of glass, stone, brick, pantile, wood and slate. The lowest readings occurred on glass, and therefore this substance exhibited the greatest radiating power; the next in order were wood, slate, pantile, brick and stone successively; the three last-named substances were nearly equal.

Metals formed a fifth class; these consisted of tinfoil, lead, zinc, copper, iron, white tin, blackened tin, and the thermometer placed in the focus of a polished metallic reflector; of these lead and zinc of different thicknesses were experimented upon, and the same results were obtained (see Table XLVII.), from which circumstance it is inferred that the thickness of a metal has no effect on its radiating power. The metals were all placed on grass, and from the circumstance of the ready passage of heat from one part of a metal to another, much heat must have passed from the earth to their upper surface when so placed. The lowest readings of this class were those of the thermometer in the focus of the reflector; the next in order, and very nearly equal to it in amount, was copper, then blackened tin, lead, zinc, iron and white tin. Two of these metals, viz. lead and zinc, were placed at different distances from the earth, the plane of each sheet being parallel to the horizon in all cases, and in every individual experiment the same result was obtained as that exhibited in the means, viz. that a metal when raised above the ground, though only by one inch, was always warmer than one on the grass, though in the latter case, from its great conducting power for heat, some must have been received from the earth, whilst in the former case, heat only could have been derived from the air flowing past both its under as well as its upper surface.

The temperature of metals as exhibited in these results, contrary to what was expected, is much below that of the surrounding air; this is particularly the case with copper; this metal radiates heat so freely, that with respect to its amount, it would be placed in the second class of substances. Many simultaneous experiments were made with copper when placed on one of the angles of the box, within which was placed the thermometer in the parabolic reflector, with the readings of the latter thermometer; thus situated, the thermometer in the box was protected from lateral wind, whilst that on the copper was subject to the passing air; and thus situated the readings on the copper were lower than those in the reflector, except at times when the air was passing quickly.

Whilst speaking of metals, I may remark here that I never found the reading of a thermometer placed on a metal which had been moved successively from one part of

the grass plat to another, was lower than when it was placed on a similar piece of metal which had remained unmoved.

A piece of metal, if so placed that part of it be in contact with grass and the other part not, that part of it in contact with the grass will be at a lower temperature than that which is not in contact.

The thermometer whose bulb is in the focus of the mirror when the clouds are low remains stationary and frequently reads higher than any other thermometer however placed; the reason seems to be, that the heat radiated from the cloud being received on the reflector and reflected to the bulb in the focus, exceeds that radiated from the thermometer.

The remaining results in Table XLV. are from experiments on garden mould, gravel, saw-dust and paper; also from those made by placing the bulb of a thermometer nine inches above wood, and protected from lateral wind by wood one foot high, at the distance of nine inches from the bulb all round; and from those made by placing the bulb of a thermometer a quarter of an inch above water. Of these, paper exhibited the greatest cold; and from many unrecorded experiments, it always exhibited a great degree of cold. The next in order were saw-dust, garden mould, nine inches above wood, a quarter of an inch above water, and lastly gravel; this last-mentioned substance apparently exhibited the lowest radiating power of any substance contained in this class; but the circumstance of thermometers placed on garden mould and on gravel reading higher than when placed on other substances, was found to be in consequence of the observations having always been made on the ground, of which they formed a part, and the respective surfaces of which were readily supplied with heat from beneath, and thus prevented from exhibiting a great degree of cold from their situation and not from the nature of their substance. This was proved from the circumstance that small parcels of garden mould and gravel placed on the raised board, in which situation but little heat passed from the board to their surface, were found in a few nights to exhibit very low readings of thermometers placed on them. After having found this, I placed a thermometer with its bulb one inch below the surface of the garden mould, and at the same time another one inch below the surface of the ground under grass, and I found that the readings of the latter were usually some degrees higher than those of the former at times when the sky had been clear for some time, plainly indicating the cause of the higher readings on the surface of the mould to be the very ready passage of the heat from beneath to its surface; and, therefore, as before observed, arising from its situation and not from a property inherent in itself. I made no experiments on the amount of heat thus conducted to the surface of the mould and of gravel, but it evidently must be equal, or very nearly so, to the amount radiated from those substances. I made some experiments on the quantity and on the rapidity of heat conducted upwards from one inch below the surface of the ground under grass; these were made by placing thermometers with their bulbs one inch below the ground, on the surface of

the ground immediately under others placed on the top of long and short grass; all the observations thus taken have been copied out, and the difference between every consecutive pair of observations has been consulted with respect to the interval of time between them. The results of this investigation are contained in the following tables:—

Table XLVI.

Showing the quantity and the rapidity of heat conducted from one inch below the surface of the soil, to the surface and to the top of grass.

Year, month and day.	Mean reading of a thermometer in air at the height of four feet.	Long grass.		Short grass.				The decrease per hour in the reading of a thermometer placed			Number of hours during which the readings were frequently examined and from which the results were deduced.	
		Amount by which the reading of a thermometer read less when placed										
		On the top of long grass than that in air at the height of four feet.	On the top of long grass than that on the surface of ground under long grass.	On the top of short grass than that in air at the height of four feet.	On the top of short grass than that under short grass.	Under short grass than that one inch beneath the surface of ground.	On the top of short grass than that one inch below the surface immediately under.	On the surface of ground under long grass.	On the surface of ground under short grass.	One inch below the surface of ground under short grass.	Long grass.	Short grass.
	°	°	°	°	°	°	°	°	°	°	h	h
1843, Dec. 11.	40·0	8·2	10·0	7·4	7·2	3·7	10·9	0·5	0·8	0·6	6	5
14.	44·9	6·0	3·4	5·6	2·6	1·5	4·1	0·3	0·4	0·7	2	2
15.	45·7	5·3	3·5	5·2	1·8	1·2	3·0	0·3	1·3	0·7	13	1
15.	45·7	...	...	...	...	...	...	...	0·6	0·4	...	4
17.	42·3	7·7	7·2	6·8	4·9	2·4	7·3	0·2	0·3	0·4	10	10
1844, Jan. 6.	43·5	...	...	5·1	1·9	3·4	5·3	...	1·0	1·0	...	2
22.	35·9	10·0	7·5	8·9	7·2	1·8	9·0	1·1	1·2	0·6	2	3
26.	42·7	9·8	4·5	7·4	1·5	3·3	4·8	0·3	0·6	0·8	2	2
30.	44·9	8·4	5·5	6·6	1·5	1·4	2·9	0·5	...	1·1	1	1
Feb. 1.	31·7	7·2	9·2	5·5	6·9	2·1	9·0	0·4	0·4	0·4	6	6
15.	34·6	10·6	11·5	7·7	7·3	2·9	10·2	0·4	0·1	0·4	4	4
16.	39·6	8·7	7·0	8·0	4·9	1·2	6·1	0·7	0·5	0·8	6	5
20.	33·4	...	...	6·7	6·5	3·0	9·5	...	1·1	0·3	...	3
22.	25·8	7·5	13·7	6·1	10·9	2·1	13·0	0·3	0·2	0·2	12	12
28.	35·0	6·2	8·0	...	...	...	...	0·3	...	...	7	
March 20.	30·8	8·4	12·8	...	...	...	...	0·3	...	...	9	
21.	37·6	10·8	9·2	...	...	...	...	0·4	...	...	2	
23.	39·7	12·5	11·4	...	...	...	...	0·3	...	...	1	
April 1.	42·0	9·7	11·1	8·4	5·8	5·4	11·2	0·6	0·3	0·2	10	8
2.	49·2	9·7	8·4	8·2	5·4	3·8	9·2	1·8	1·0	1·2	4	4
3.	47·0	11·4	8·8	9·5	2·5	3·3	5·8	0·4	0·1	0·6	11	6
8.	44·9	13·0	8·3	11·2	6·8	3·4	10·2	0·6	0·4	0·8	10	7
9.	52·6	13·0	9·2	11·2	3·6	5·3	8·9	0·8	1·0	1·0	1	1
17.	46·5	9·4	7·5	9·0	4·0	5·5	9·5	0·4	0·3	0·4	6	8
18.	42·1	11·9	12·4	...	...	...	...	0·7	...	...	9	
23.	54·7	7·3	5·5	7·0	3·0	2·7	5·7	1·2	0·8	1·6	2	1
24.	45·5	15·0	13·7	12·8	5·4	7·7	13·1	1·0	1·2	0·3	3	3
25.	50·2	10·0	9·2	9·1	4·0	6·0	10·0	2·0	2·0	1·5	12	10
27.	47·0	...	...	9·0	9·9	6·3	16·2	...	2·1	2·2	...	2
29.	40·8	8·3	5·8	7·3	7·8	1·9	9·7	1·2	0·6	0·2	2	4
May 1.	46·0	11·4	11·0	9·9	5·8	6·1	11·9	1·2	1·2	1·2	10	9

By taking the mean of the numbers in each column, we find that—

The mean reading of a thermometer placed on long grass was less than that in air by . . . . . 9°·5

The mean reading of a thermometer placed on short grass was less than that in air by . . . . . 8°·0

The mean reading of a thermometer placed on long grass was less than that under long grass by . . . . . 8°·7

The mean reading of a thermometer placed on short grass was less than that under short grass by . . . . . 5·2

The mean reading of a thermometer placed under short grass was less than that one inch below the surface of the ground under short grass by . . 3·5

The mean reading of a thermometer placed on short grass was less than that one inch below the surface of the ground under short grass by . . . . 8·7

The mean rate of decrease in the reading of a thermometer placed under long grass was, per hour . . . . . 0·7

The mean rate of decrease in the reading of a thermometer placed under short grass was, per hour . . . . . 0·8

And the mean rate of decrease in the reading of a thermometer placed one inch below the surface under short grass was, per hour . . . . . 0·75

In this investigation the excess of the reading of a thermometer placed one inch below the surface of the ground under long grass, above that placed on the surface of the ground, has not been deduced; from a few experiments it appeared to be exactly the same as that of short grass; and assuming such to be the case, the mean difference on clear and calm nights between the reading of two thermometers, the one placed on long grass and the other placed one inch below the ground immediately underneath the other, was 13°·0; and the same difference with respect to short grass was 11°·5. As the results contained in this table were deduced from observations taken at times when the temperature of the long grass was above 30° generally, and occasionally a little below 30°; and as it appears from the remarks following Table XLV. that at temperatures much below 30° very great differences occurred with grass of different lengths, it was desirable to investigate observations similar to the above at low temperatures: such observations I took only on one night, viz. that of March 13, 1845; during this night the thermometers were read hourly for eight hours, and during the time—

The mean reading of the thermometer in air at the height of four feet was . 15·1

The mean reading of the thermometer on long grass was . . . . . 5·6

The mean reading of the thermometer on the surface of the soil under long grass was . . . . . 26·9

The mean reading of the thermometer one inch beneath the surface of the ground under long grass was . . . . . 33·1

The mean reading of the thermometer on short grass was . . . . . 11·1

The mean reading of the thermometer on the surface of the ground under short grass was . . . . . 21·4

The mean reading of the thermometer one inch beneath the surface of the ground under short grass was . . . . . 28·2

The results of these experiments exhibit in a marked manner the badness of the conducting power of grass for heat, the reading on long grass being less than that on

the surface of the ground immediately beneath it by 21°·3, and less than that one inch below the surface by 27°·5; and the reading of that on short grass was less than that on the ground immediately beneath it by 10°·3, and less than that one inch beneath the surface of the ground by 17°·1. The mean rate of decrease of temperature at one inch beneath the surface of the ground under long grass was 0°·2 per hour, and under short grass was 0°·3 per hour; and on the surface of the ground under short grass was 0°·4 per hour. The difference between the readings at one inch beneath the surface under long grass and under short grass was 4°·9, the former being the higher by this amount; the difference between the readings on the surface of the soil under long grass and under short grass was 5°·4, that under long grass being the higher of the two; and the difference of readings on long grass and on short grass was 5°·4, that on long grass being the lower of the two; and thus the reading on long grass was as much less than that on short grass as that under long exceeded that under short: this circumstance affords a sufficient reason for the temperature of short grass being warmer than that of long grass, the heat passing so much more freely from the earth to it than in the case of long grass.

I shall conclude this part of this section, with remarking that the various amounts of dew deposited, at the same time, on different bodies at night, were found to be, as near as could be determined, proportional to the amounts of the depression of their temperature below that of the dew-point. Hence, it is evident that all hygrometers formed of any of these substances, or of any animal or vegetable substance, when exposed to the clear sky at night, will be cooled by the radiation of their heat, and will cool the air in contact with them; and thus indicate a greater degree of humidity than actually exists; and particularly so, should their temperatures descend below that of the dew-point, and dew be actually deposited upon them.

The following table contains the results of special simultaneous observations, made in some cases in consequence of the results as deduced from the ordinary observations not agreeing with each other, and in others to determine the amount of the correction due to the placing of the different substances on the raised board.

Table XLVII.—Results of Special Simultaneous Observations.

Excess of the reading of the thermometer in air at the height of four feet protected from the effects of radiation, above those of thermometers, in simultaneous observations, placed

1843. Day, hour and minute.	One inch above grass.	Two inches above grass.	1843. Day, hour and minute.	On white unwrought cotton wool.		1843. Day, hour and minute.	On flax.		1843. Day, hour and minute.	On sand.		1843. Day, hour and minute.	On zinc.			1843. Day, hour and minute.	On stone.			1844. Day, hour and minute.	On lead.		1844. Day, hour and minute.	In air. Height in feet.		
				On grass.	On the raised board.		On grass.	On the raised board.		On the ground.	On the raised board.		Thin.	Moderately thick.	Thick.		Fire.	Portland.	Purbeck.		On grass.	Six inches above grass.		8.	18.	12.
Sept. h m	°	°	h m	°	°	Nov. h m	°	°	Sept. h m	°	°	h m	°	°	°	h m	°	°	°	Feb. h m	°	°	Feb. h m	°	°	°
13. 12 0	12·0	7·5	Sept. 13. 13 30	11·7	11·8	7. 10 0	6·5	5·5	13. 12 0	7·5	7·5	Nov. 29. 12 30	6·0	4·3	5·0	Dec. 11. 4 30	2·2	2·4	2·7	1. 5 0	8·3	4·5	21. 11 0	0·0	0·1	0·2
13. 12 30	12·3	6·8	13. 14 30	11·5	10·0	7. 11 10	6·5	4·3	13. 12 30	7·8	8·3	29. 13 45	5·7	6·0	6·0	11. 5 30	2·5	2·9	3·1	1. 7 0	3·8	4·0	22. 6 45	1·2	1·3	1·3
13. 13 20	11·7	5·7	13. 15 15	12·3	10·0	8. 9 10	8·0	5·8	13. 13 30	9·2	8·9	29. 15 0	5·3	5·5	5·8	11. 6 30	3·0	4·0	3·0	1. 9 0	3·7	4·7	22. 9 0	0·8	0·8	0·1
13. 14 30	10·5	5·2	13. 15 20	9·5	8·3	8. 11 0	8·6	6·1	13. 14 30	8·5	7·5	29. 17 0	1·8	3·9	3·8	11. 9 30	2·3	2·6	1·9	15. 15 0	6·3	5·0	22. 11 30	2·4	2·1	2·4
13. 15 15	10·3	5·3	13. 15 24	6·0	5·5	11. 5 30	8·3	8·3	13. 15 15	8·8	8·3	29. 18 0	2·5	3·9	3·7	13. 18 0	3·0	2·5	2·0	15. 17 30	7·5	4·9	22. 12 30	0·8	0·8	0·8
13. 15 20	8·5	4·5	13. 15 37	4·5	4·5	11. 7 30	13·2	10·2	13. 15 20	7·0	5·0	29. 19 0	4·0	4·7	4·5	14. 3 0	2·2	2·4	1·9	15. 18 30	7·3	6·3	22. 13 0	1·3	1·3	1·6
13. 15 24	6·0	3·5	13. 17 20	5·5	5·5	11. 9 50	9·5	7·5	13. 15 24	6·0	5·0	Dec. 2. 3 40	3·6	3·3	3·0	14. 4 0	2·5	2·6	2·5	15. 19 15	6·5	5·0	22. 14 30	0·9	0·8	1·0
13. 15 37	4·5	3·0	Oct. 25. 5 15	13·4	14·5	11. 10 35	10·5	7·4	13. 15 37	4·5	4·0	2. 4 30	4·7	4·5	4·0	14. 5 0	2·6	2·9	2·2	16. 4 30	7·7	4·5	22. 16 0	0·6	0·8	0·7
13. 17 20	5·5	3·5	25. 8 0	11·6	10·3	11. 11 10	13·3	9·7	13. 17 20	5·5	4·5	5. 16 15	7·2	6·7	6·9	15. 3 45	1·9	1·7	1·7	16. 5 30	10·0	7·0	22. 17 30	0·2	−0·1	0·1
			25. 9 30	13·0	11·7	11. 12 0	9·5	7·5	13. 17 20	3·2	2·2	5. 17 30	5·6	5·3	5·3	15. 5 0	2·9	2·6	2·9	16. 7 0	5·7	3·2	22. 18 45	−0·1	0·0	0·0
			25. 11 40	10·8	11·0	12. 4 0	5·9	4·3	15. 9 10	3·5	5·3	5. 19 30	5·8	5·5	5·8	15. 21 0	3·0	3·8	2·8	16. 8 0	5·5	2·5				
			25. 13 0	9·5	10·2				15. 10 33	5·0	7·3	5. 21 0	4·5	4·7	4·3	17. 4 0	2·2	3·2	3·2	16. 9 0	6·3	2·8				
			25. 15 0	8·9	9·9				15. 11 0	5·3	6·8	6. 3 45	4·6	4·1	4·2	1844.										
			25. 18 15	9·0	8·8				16. 7 40	4·0	3·4	6. 4 15	5·3	5·2	5·0	Jan. 17. 5 0	4·3	3·5	3·4		One foot high.	Three feet high.				
			25. 19 30	7·5	6·2				16. 9 10	3·6	4·8	6. 4 45	5·9	5·7	5·9	26. 5 10	5·3	4·8	5·0							
			25. 21 0	6·1	2·6				16. 11 20	3·4	3·5	6. 11 0	3·2	3·2	4·2	26. 7 30	4·7	4·1	4·5							
									17. 11 0	3·3	3·8	6. 14 0	5·0	4·5	4·8	30. 4 30	5·3	4·0	4·6							
									17. 11 30	4·2	4·3	8. 4 30	9·1	8·1	9·1	30. 5 30	3·5	2·6	3·1	May h m	°	°				
									17. 12 30	3·6	4·2	8. 9 30	8·5	8·5	8·3	Feb. 1. 3 30	2·7	2·7	2·4	1. 15 0	6·7	5·7				
									17. 13 20	3·4	3·3	11. 3 55	7·0	6·8	6·8	1. 5 0	4·5	6·0	4·0	1. 17 0	4·2	4·8				
									17. 15 20	2·8	2·7	11. 4 30	7·2	7·2	7·2	1. 7 0	0·5	2·0	4·2							
									17. 17 20	2·9	2·6	11. 5 30	5·4	6·0	6·1	1. 9 0	2·7	2·0	2·7							
									18. 7 30	4·0	3·8	11. 6 30	4·8	4·8	4·8	15. 15 0	4·3	4·3	4·6							
									18. 8 0	4·1	3·9	11. 9 30	5·6	5·2	5·2	15. 17 30	2·8	2·8	5·0							
									18. 9 0	8·0	6·0	13. 18 0	3·5	3·5	3·2	15. 18 30	2·5	1·5	4·5							
												14. 3 0	3·9	3·7	3·7	15. 19 15	3·8	3·3	6·0							
												14. 4 0	4·5	4·5	4·5	16. 4 30	4·5	4·7	5·7							
												14. 5 0	4·2	4·2	4·2	16. 5 30	5·0	5·0	5·8							
												15. 3 45	3·2	3·5	3·1	16. 7 0	4·4	4·7	5·4							
												15. 5 0	4·0	3·8	3·8	16. 8 0	3·5	3·3	4·0							
												17. 4 0	5·5	5·5	5·5	16. 9 0	4·6	4·0	5·1							
																20. 5 0	4·5	4·9	4·7							

TABLE XLVIII. Abstract of Special Simultaneous Observations.

Situation of the thermometer.	Excess of air-temperature above the reading of thermometer.	Number of simultaneous observations.	Remarks.
	°		
One inch above grass	9·0	9	The observations at the height of two inches were made on one night only.
Two inches above grass	5·0		
On white unwrought cotton wool { on grass	9·4	16	It would seem that the amount of radiation from the raised board was less than that from the same substance on the ground.
on the raised board	8·8		
On flax { on grass	9·0	11	The amount of radiation from flax on the raised board decidedly the smaller.
on the raised board	6·9		
On sand { on the ground	5·6	25	The sand on the board was a small quantity, whilst that on the ground was a large quantity; the amount of radiation from sand on the raised board was the smaller.
on the raised board	5·1		
On zinc { thin	5·1	31	From these it would appear that the thickness of a metal has no influence on the amount of its radiating power.
moderately thick	5·0		
thick	5·1		
On firestone	3·3	31	The circumstance of Purbeck stone having a result larger than the other two is probably accidental, as on many nights its results were less than those of the other stones.
On Purbeck stone	3·7		
On Portland stone	3·3		
On lead on grass	6·5	12	The increase in the readings of a thermometer placed on a metal, raised in the air, is decided.
On lead six inches above grass placed horizontally	4·5		
In air at eight feet high	0·8	10	The results are identical, and therefore in Table XLV. such should be the case in the mean.
In air at ten feet high	0·8		The observations at ten feet were made on one night only.
In air at twelve feet high	0·8		
On lead one foot high	5·5	2	The increase in the readings of a thermometer with height is indicated.
On lead three feet high	5·3		

The remarks in the last column indicate the results of the experiments; those relating to the different readings of a thermometer when placed on the same substance on the raised board and on the grass, seem to exhibit in a decided manner that more heat had passed from the board to the surface of the substance than had passed from the grass to it, causing the reading of the thermometers to be increased; the amount of this increase appears to be about half a degree, and this amount should be applied subtractively to all readings on substances placed on the raised board, or additively to all differences between their readings and those in air at the height of four feet.

In Table XLV. the results from all substances in powder were deduced from observations on the raised board, and from this investigation all these results should be increased by half a degree; in the same table the results from blue and yellow jeweller's wool and from raw silk exhibit a greater degree of cold on the raised board than when they were on grass; but these substances were never observed simultaneously in both positions, and they were only placed on the raised board on the finest and calmest nights, and in this latter position they require the same correction to be applied to them as it is necessary to apply to the other substances, whose results are deduced from observations taken on the raised board alone.

Table XLIX.

Observations connected with Snow.

1844. Day, hour and minute.	Reading of thermometer in air at four feet high, protected from radiation.	Excess of the reading of a thermometer placed in air at the height of four feet and protected from the effects of radiation, above that of a thermometer fully exposed to the sky, and placed: On long grass clear of snow.	On long grass covered by snow.	On short grass clear of snow.	On short grass covered by snow.	On surface of ground under short grass clear of snow.	On surface of ground under long grass clear of snow.	One inch below surface of ground under grass covered by snow.	On grass cleared of snow covered by glass free of snow one inch high.	On grass clear of snow covered by white tin one inch high.	On snow.	On raw wool on snow.	On flax on snow.	In focus of metallic reflector cleared of snow.	Nine inches above wood cleared of snow.	One foot above snow.	Two feet above snow.	On lead six inches high cleared of snow.	On copper on snow.	On zinc on snow.	On zinc on grass cleared of snow.	On Purbeck stone cleared of snow.	On glass on snow.	On glass one inch high cleared of snow.	On white tin on snow.	On black tin on snow.	Clouds: Modification.	Amount 0 - 10.	Wind: High or low.	Direction.	Strength 0 - 6.	Haze, fog, mist, or vapour.	Remarks.
Feb.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°							
4. 15	31·6	7·6	...	5·4	...	...	...	...	...	...	...	9·8	9·8	9·3	...	1·8	1·9	...	...	...	...	...	...	4·8	9·0	Clear	...	...			H.	Snow to the depth of three inches was on the ground.
4. 19	29·7	6·5	...	5·1	...	...	...	...	...	...	...	8·1	8·0	8·7	...	2·3	2·7	...	...	...	...	...	...	3·5	7·5	Cirro-stratus	9	...	c.				
5. 5	31·0	8·0	−2·0	6·4	−2·7	1·8	...	−5·5	...	...	5·0	7·0	6·5	9·9	...	1·7	1·7	...	...	5·2	...	...	6·8	7·8	7·8	9·7	Clear	...	...			H.	
5. 7	25 29·0	9·2	−3·0	9·6	−2·8	−1·8	...	−5·3	4·2	...	6·8	8·2	9·2	10·9	...	2·0	2·0	6·2	...	6·0	...	...	10·4	5·6	7·8	8·8	Flying clouds	3	...			H.	
6. 11	33·1	5·1	1·1	5·9	2·6	2·6	0·1	−1·9	1·6	3·6	2·6	7·6	8·0	7·6	2·1	0·9	0·9	...	5·1	3·9	3·6	2·6	5·6	4·0	5·6	6·1	Cirro-stratus	9½	H.	c.				

By taking the mean of the numbers in each column, the following results are obtained:—

Table L. Experiments connected with Snow.

Situation of the thermometer, its bulb, or the substance under which it was placed being fully exposed to the sky.	Mean excess of the reading of the thermometer in air at the height of four feet, protected from radiation.	Number of comparisons.
	°	
On long grass clear of snow	7·3	5
On long grass covered by snow	−1·3	3
On short grass clear of snow	5·5	5
On short grass covered by snow	−1·0	3
On surface of ground under short grass clear of snow	0·9	3
On surface of ground under long grass clear of snow	0·1	1
One inch below surface of ground under long grass covered by snow	−4·2	3
On grass cleared of snow covered by glass free from snow one inch high	2·9	2
On grass clear of snow covered by white tin one inch high	3·6	1
On snow	4·8	3
On raw wool on snow	8·2	5
On flax on snow	8·3	5
In focus of metallic reflector cleared of snow	9·3	5
Nine inches above wood cleared of snow	2·1	1
One foot above snow	1·7	5
Two feet above snow	1·8	5
On lead six inches high cleared of snow	6·2	1
On copper on snow	5·1	1
On zinc on snow	5·0	3
On zinc on grass cleared of snow	3·6	1
On Purbeck stone cleared of snow	2·6	1
On glass on snow	7·6	3
On glass one inch high cleared of snow	5·8	3
On white tin on snow	5·9	5
On blackened tin on snow	8·2	5

At the time of two of these five sets of observations the sky was nearly covered with cloud; at one other time one-third part of the sky was clouded over and much haze prevailed; and at the remaining times the sky was not bright, and there was a perceptible haze. The mean temperature of the air was 30°·9; the mean reading of the thermometer on long grass clear of snow was 1°·8 less than that on short grass, also clear of snow; and the readings were nearly alike when the two were covered with snow. The effects of snow on long grass was to cause the thermometers on the grass to read higher by 8°·6, but this difference does not fully represent the non-conducting power of snow, as the temperature of the air varied very little whilst these experiments were being made; had the temperature of the air fallen or risen much whilst the snow had been on the ground, the temperature of the earth under the snow would have continued nearly at the same reading, and in that case the effects of the snow would have been much more decided. The next favourable opportunity I had of repeating my experiments on snow was 1845, February 12*. Snow had previously fallen to the depth of three inches, and during the night, which was cloudless, the reading of a thermometer which was placed on long grass was −6°, whilst that covered by snow was 28°·0; the effect of the snow was therefore to keep the grass warmer by 34°, and therefore vegetation was kept warmer by this amount than it would have been had there been no snow. The reading of a thermometer placed on the snow was −12°, and the difference between the readings of two thermometers, the one placed on snow and the other under the snow, was 40°. After this time the reading on grass clear of snow rose to 24°, and that on snow increased to 15°, without causing any variation in the reading of that under the snow, which still read 28°. Snow would therefore appear to be a very perfect non-conductor of heat. The lowest reading of a thermometer on flax was −12°½; that on short grass was 5°, being 11° higher than that on long grass; this heat (see remarks following Table XLV.) represents the difference between the quantities of heat conducted from beneath the surface to long and to short grass, and it would represent also the greater quantity of heat lost from the earth as covered by short grass than that by long grass; and if to this 11° we add the heat conducted beneath the surface to long grass, which did not differ much from 6°, it would appear that heat to the amount of 17° was conducted to the short grass from the earth beneath it. Snow being so perfect a non-conductor of heat, evidently prevents to a high degree the loss of heat by radiation from bodies covered by it; and it also prevents the loss of heat from such bodies by conduction, at times when the temperature of the air is lower than they are. Raw wool, flax, straw, and other bodies which are bad conductors of heat, act in a similar way and prevent the injurious effects of cold to bodies covered by them, to which injurious effects vegetation is liable in this climate in every month of the year, as it is liable to a temperature at night below the freezing-point of water in every month.

* For these observations, see the Greenwich Magnetical and Meteorological volume for the year 1845, pages 256 and 257.

Section II.—*Results of Observations made by Self-registering Minimum Thermometers.*

These observations extend over a period of time of nearly four years' duration, viz. from 1841 February to the end of 1844*.

The observations consist of the daily reading of a self-registering minimum thermometer with its bulb placed at the height of four feet above the ground, protected from the effects of radiation and rain, but in other respects freely exposed to the air, and the daily reading of a similar thermometer placed with its bulb in the focus of a metallic parabolic reflector, and fully exposed to the sky.

The kind and average amount of cloud by which the sky was covered were also noted every night. The average direction and strength of the wind were also determined every night.

From 1843 April and extending to the end of 1844, several similar thermometers were placed on or near different substances, and their readings were taken daily.

The first process in the reduction of the observations was the taking the difference between the reading of the thermometer in air and the simultaneous reading of every other thermometer.

The second process was the forming all those differences into groups, according to the variable state of the sky, depending only on the kind and amount of cloud, but independently of its height. The result of this investigation was found to be that the amount of the difference varied with every variation of the amount of the clouds.

The third process was the forming groups of the differences derived from the same cloudy state of the sky, but with the clouds at different distances from the earth. The result was found to be that the amount of the numbers was different according to the variable distance that the clouds were from the earth.

The fourth step was the forming groups of numbers derived from observations on different nights with the same state of the sky, but with the wind blowing from different quarters, independently of its strength. The result of this investigation was that no certain difference existed depending on the quarter from whence the wind blew.

The fifth step was the forming groups of the numbers found from observations on different nights with the same state of the sky, on calm nights, and on nights when the wind has been blowing strongly, at times amounting to a gale, independently of its direction. The result was found to be that no certain difference existed, depending on the strength or velocity of the wind, showing clearly that on every windy night a portion of time had been calm of sufficient duration for the instruments to register the loss of heat by radiation, and to the same amount as would have been shown had the air been in a calm state during the night.

Having thus explained the manner in which the preliminary steps in the reduction

* The observations are placed in the Archives of the Royal Society.

of the observations have been made, I shall proceed with the explanation of the process for the formation of the following tables.

As the variations of the excess of the readings of the thermometer in the air, above those otherwise placed, were thus found to depend on the variations in the amount and in the height of the clouds only, the next operation was dividing the results of each month's observations into five groups as follow.

The first group was formed from the observations taken on nights which were cloudy throughout.

The second group from those taken on nights which were principally cloudy, but the clouds frequently broken.

The third group from those taken on nights which were half-clear and half-cloudy.

The fourth group from those taken on nights which were principally cloudless, but yet clouds were frequent.

The fifth group from those taken on cloudless nights, and in this way Tables LI. to XCIX. were formed; the successive results in each class being arranged according to their dates of occurrence.

The examination of the columns in each month as to the distribution of the numbers, gives a good knowledge of the distribution of the clouds at night during the month.

Excess of the reading of a self-registering minimum thermometer placed in air at the height of four feet, protected from the effects of radiation, above that of a similar thermometer placed in the focus of a metallic parabolic reflector fully exposed to the sky on every night, arranged according to the state of the sky with respect to the quantity of clouds.

Number of the Tables.	1841. Month.	General state of the sky during the night previous to reading the instruments.									
		Cloudy.		Broken clouds.		Half-cloudy.		Principally clear.		Cloudless.	
		Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.
		d h	°	d h	°	d h	°	d h	°	d h	°
LI.	Feb.	4 21	4·8	24 21	3·8	17 21	.....	.....	.....	19 21	5·8
		5 21	3·0	28 21	4·1	18 21	3·2				
		6 21	0·8								
		7 21	2·8								
		8 21	2·3								
		9 21	2·8								
		10 21	5·7								
		11 21	1·9								
		12 21	1·7								
		13 21	0·8								
		14 21	−0·6								
		15 21	1·2								
		16 21	2·9								
		20 21	2·3								
		21 21	2·1								
		22 21	1·1								
		23 21	1·5								
		25 21	2·4								
		27 21	1·3								
LII.	March	13 21	−0·5	1 21	1·8	7 21	5·8	2 21	5·2	6 21	9·4
				4 21	2·1	9 21	5·3	3 21	4·9	8 21	7·2
		30 21	2·0	20 21	3·5	14 21	4·2	5 21	5·1	10 21	4·7
		31 21	0·2	23 21	4·0	22 21	4·3	17 21	9·7	11 21	7·0
				28 21	4·4	26 21	5·9	18 21	5·4	12 21	5·3
										15 21	8·8
										16 21	13·4
										19 21	6·7
										24 21	7·3
										25 21	6·9
										27 21	5·7
										29 21	2·7
LIII.	April	10 21	2·1	1 21	3·5	5 21	4·5	14 21	7·2	2 21	8·6
		13 21	2·8	6 21	2·7	9 21	4·7	21 21	3·5	3 21	7·8
		22 21	0·7	7 21	1·9	12 21	6·6	23 21	6·5	4 21	11·5
		24 21	2·1	11 21	1·3	19 21	7·9	26 21	5·6	8 21	11·8
				18 21	(−2·4)	20 21	4·7	28 21	5·6	15 21	7·6
				25 21	6·3	27 21	5·4	29 21	6·2	16 21	10·2
										30 21	8·1

TABLE (Continued).

Number of the Tables.	1841. Month.	General state of the sky during the night previous to reading the instruments.									
		Cloudy.		Broken clouds.		Half-cloudy.		Principally clear.		Cloudless.	
		Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.
LIV.	May	d h 2 21 3 21 4 21 21 21 25 21 29 21	° 0·2 0·1 −0·1 0·2 0·6 1·5	d h 5 21 6 21 7 21 8 21 9 21 11 21 18 21 27 21	° 3·9 3·2 −0·4 2·5 1·1 3·5 0·5 2·1	d h 10 21 16 21 17 21 19 21 22 21 23 21	° 5·3 5·5 5·4 3·7 5·5 5·4	d h 24 21 28 21 30 21 31 21	° 6·6 5·4 7·5 8·4	d h 1 21 12 21 13 21 14 21 15 21 20 21 26 21	° 7·7 8·5 7·8 7·5 8·0 5·9 5·3
LV.	June	5 11 7 21 8 21 11 21 18 21 24 21 27 21	−0·7 −1·1 0·8 −0·4 1·4 ..... 0·6	2 21 6 21 14 21 ..... 28 21 30 21	2·3 5·6 3·7 ..... 1·9 3·5	4 21 16 21 19 21 21 21 22 21 25 21 29 21	7·9 5·1 4·9 4·9 4·6 (−0·3) 4·5	1 21 10 21 13 21 15 21 17 21 23 21	5·9 7·8 6·7 8·3 9·4 6·2	3 21 9 21 12 21 20 21 26 21	9·2 9·4 11·2 3·5 (−0·3)
LVI.	July	1 21 2 21 3 21 7 21 10 21 15 21 23 21	−0·3 1·4 1·3 −0·3 0·3 1·5 1·7	4 21 11 21 14 21 19 21 20 21 21 21 22 21 25 21 26 21 27 21 31 21	3·6 2·8 1·9 3·1 3·6 2·9 2·3 2·1 3·4 3·7 2·2	12 21 18 21 24 21 28 21 29 21 30 21	5·3 5·2 4·6 4·1 4·7 4·2	4 21 8 21 13 21	7·0 2·1 4·9	3 21 9 21 16 21 17 21	10·9 3·8 8·0 6·8
LVII.	August	1 21 2 21 3 21 10 21 17 21 22 21 25 21 31 21	0·1 −0·6 −1·3 0·5 1·8 0·3 1·6 2·2	4 21 5 21 7 21 8 21 13 21 16 21 26 21	5·0 3·5 3·8 3·0 2·5 3·9 3·2	6 21 11 21 12 21 14 21 23 21 30 21	7·9 4·5 6·5 5·5 5·1 5·0	9 21 15 21 18 21 19 21 21 21 27 21	3·3 6·5 6·4 5·2 6·2 6·0	20 21 24 21 28 21 29 21	7·0 10·5 8·2 14·0
LVIII.	Sept.	4 21 20 21	2·9 2·3	27 21 29 21	4·0 4·5	3 21 5 21 7 21 8 21 9 21 11 21 14 21 19 21 21 21 22 21 23 21 24 21 25 21 26 21 28 21 30 21	8·4 5·6 5·3 4·5 4·8 4·1 5·5 4·1 3·3 4·3 4·7 5·2 4·3 2·7 4·0 4·1	1 21 2 21 13 21 16 21	6·7 6·1 3·6 5·8	6 21 10 21 12 21 15 21 17 21 18 21	4·5 10·5 11·7 7·1 7·1 7·9

Table (Continued).

Number of the Tables	1841. Month.	General state of the sky during the night previous to reading the instruments. Cloudy. Day and hour of reading.	Cloudy. Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Broken clouds. Day and hour of reading.	Broken clouds. Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Half-cloudy. Day and hour of reading.	Half-cloudy. Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Principally clear. Day and hour of reading.	Principally clear. Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Cloudless. Day and hour of reading.	Cloudless. Excess of the reading of the thermometer in air above that placed in the focus of the reflector.
LIX.	Oct.	d h 27 21 28 21 29 21 30 21 31 21	° 6·6 2·1 2·7 6·0 2·1	d h 1 21 2 21 3 21 4 21 5 21 10 21 11 21 13 21 26 21	° 3·6 2·5 1·0 3·1 3·1 3·4 3·2 3·4 2·1	d h 6 21 7 21 8 21 9 21 12 21 14 21 14 21 22 21 23 21 24 21 25 21	° 2·4 2·4 3·4 4·6 4·4 4·1 4·5 3·4 4·7 4·2 3·5	d h 15 21	° 1·0	d h 16 21 17 21 19 21 20 21 21 21	° 4·2 [2·4] 6·7 2·4 2·4
LX.	Nov.	1 21 21 21 27 21	2·4 2·0 2·7	3 21 4 21 7 21 9 21 13 21 15 21 20 21 28 21 29 21	2·2 −1·1 4·1 3·2 6·0 1·1 2·4 2·9 3·0	2 21 3 21 10 21 24 21 25 21 30 21	3·9 4·3 5·7 5·9 5·7 6·1	22 21 23 21 26 21	1·0 6·7 2·9	6 21 8 21 11 21 12 21 14 21 16 21 17 21 18 21 19 21	3·0 2·2 3·4 3·4 2·2 [0·0] 3·2 2·6 3·6
LXI.	Dec.	19 21 28 21 29 21	2·5 2·3 2·2	2 21 7 21 12 21 24 21 25 21 27 21	3·3 3·9 4·0 1·0 3·7 2·4	1 21 4 21 5 21 9 21 11 21 13 21 15 21 22 21 30 21	5·1 5·0 5·4 6·1 5·9 4·4 5·4 4·2 5·6	3 21 8 21 16 21 21 21 23 21	6·9 2·1 4·0 6·6 6·7	6 21 10 21 14 21 17 21 18 21 20 21 26 21	2·2 2·4 2·4 2·3 [1·4] 2·5 6·3
LXII.	1842. Jan.	8 21 9 21 10 21 11 21 13 21 18 21 19 21 20 21 21 21 29 21	2·1 2·5 2·5 1·4 2·4 2·0 2·2 0·6 3·0 1·5	0 21 2 21	5·0 2·7	1 21 3 21 4 21 5 21 17 21 28 21 30 21	7·6 8·7 8·7 8·5 3·6 6·6 5·3	6 21 12 21 13 21 16 21 22 21 26 21 31 21	3·5 7·3 7·0 4·9 6·4 5·5 6·1	7 21 14 21 23 21 24 21 25 21 27 21	6·0 9·1 10·7 10·7 9·1 [2·0]
LXIII.	Feb.	7 21 11 21 16 21 23 21 24 21	1·6 1·0 2·6 1·4 2·3	3 21 4 21 8 21 9 21 10 21 22 21	3·7 3·3 1·2 2·5 3·4 3·9	3 21 5 21 12 21 20 21 21 21 27 21 28 21	4·3 5·0 7·2 6·4 5·4 5·4 5·6	1 21 6 21 14 21 18 21 19 21	7·3 5·7 5·4 5·0 5·5	13 21 15 21 17 21 25 21	6·0 8·9 9·4 9·3

TABLE (Continued).

Number of the Tables.	1842. Month.	General state of the sky during the night previous to reading the instruments.									
		Cloudy.		Broken clouds.		Half-cloudy.		Principally clear.		Cloudless.	
		Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.
LXIV.	March	d h 2 21 7 21 9 21 14 21 15 21 24 21 29 21 31 21	° 3·2 1·4 2·5 0·5 1·3 2·5 2·5 1·6	d h 19 21	° 1·6	d h 3 21 5 21 8 21 11 21 16 21 17 21 20 21 21 21 27 21 28 21 30 21	° 4·1 4·9 4·3 4·1 6·4 4·5 3·8 3·6 3·3 3·2 4·2	d h 18 21 22 21 23 21	° 7·4 5·6 6·7	d h 1 21 4 21 6 21 10 21 12 21 13 21 25 21 26 21	° 7·4 4·1 6·4 8·2 6·8 6·5 6·3 6·3
LXV.	April	12 21 13 21 14 21 18 21 21 21	2·2 0·9 2·8 0·7 0·6	11 21	3·9	1 21 2 21 7 21 9 21 10 21 22 21 23 21 29 21	4·9 4·9 4·8 4·6 4·3 4·6 6·9 3·7	3 21 4 21 6 21 15 21 16 21 20 21 24 21	7·9 7·7 3·8 3·7 4·3 2·5 5·9	5 21 8 21 17 21 19 21 25 21 26 21 27 21 28 21 30 21	7·5 4·4 8·1 5·6 6·6 7·0 9·3 7·6 7·7
LXVI.	May	3 21 11 21 27 21	2·3 1·7 1·7	5 21 6 21 12 21 20 21 21 21	5·7 1·6 6·1 5·3 6·4	7 21 14 21 15 21 18 21 25 21	5·9 4·4 5·7 7·7 6·9	4 21 8 21 10 21 16 21 17 21 19 21 22 21 24 21 26 21 30 21	6·5 6·7 7·4 6·9 5·2 6·6 8·2 6·8 6·2 7·2	1 21 2 21 9 21 13 21 23 21 28 21 29 21 31 21	8·1 7·1 9·0 7·6 9·5 8·4 9·2 8·7
LXVII.	June	25 21 30 21	2·4 −0·1	24 21	5·8	14 21 16 21 17 21 18 21 19 21 20 21 23 21	5·2 6·5 6·2 6·2 5·5 5·8 4·9	1 21 4 21 13 21 15 21 21 21 27 21 28 21 29 21	8·3 6·5 5·8 6·7 5·3 5·7 6·0 7·0	2 21 3 21 5 21 6 21 7 21 8 21 9 21 10 21 11 21 12 21 22 21 26 21	9·7 8·9 9·1 15·6 16·0 7·9 7·3 6·4 6·9 7·2 12·8 14·2

Table (Continued).

Number of the Tables.	1843. Month.	General state of the sky during the night previous to reading the instruments.									
		Cloudy.		Broken clouds.		Half-cloudy.		Principally clear.		Cloudless.	
		Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.	Day and hour of reading.	Excess of the reading of the thermometer in air above that placed in the focus of the reflector.
LXXVI.	March	d h	°	d h	°	d h	°	d h	°	d h	°
		10 21	11·4	30 21	10·5	21 21	7·1	12 21	7·5	1 21	12·0
		11 21	4·3	.....	.....	22 21	7·9	16 21	8·7	2 21	17·6
		13 21	3·8	.....	.....	26 21	6·8	20 21	8·0	3 21	12·1
		14 21	2·0	.....	.....	.....	.....	23 21	8·7	4 21	11·2
		15 21	2·5	.....	.....	.....	.....	24 21	8·9	5 21	10·5
		27 21	5·7	.....	.....	.....	.....	.....	.....	6 21	14·2
		31 21	7·1	.....	.....	.....	.....	.....	.....	7 21	11·5
										8 21	10·5
										9 21	12·7
										17 21	11·2
										18 21	10·0
										19 21	6·0
										25 21	9·2
										28 21	12·3
										29 21	12·6
LXXVII.	April	1 21	3·1	2 21	2·8	3 21	6·4	8 21	5·2	4 21	8·3
		6 21	1·8	.....	.....	5 21	3·1	10 21	6·8	9 21	9·4
		14 21	3·8	.....	.....	7 21	4·2	16 21	6·6	11 21	9·4
		15 21	2·4	.....	.....	12 21	6·9	19 21	9·5	13 21	9·2
						20 21	5·3	21 21	9·0	17 21	10·3
						25 21	4·5	29 21	7·3	18 21	9·0
						26 21	5·8	.....	.....	22 21	13·0
						28 21	6·6	.....	.....	23 21	12·0
										24 21	12·4
										27 21	9·4
										30 21	9·1

Table LXXVIII.

General state of the sky during the night previous to reading the instruments.	1843. April. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air at the height of 4 feet, and protected from the effects of radiation above that placed					
			On long grass exposed to ¾ths of sky.	On short grass.	On garden mould.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h	°	°	°	°	°	°	°
Cloudless.	22 21	37·0	.....	11·2	4·0	.....	.....	13·0
	23 21	36·0	.....	6·8	4·3	.....	.....	12·0
	30 21	48·6	8·1	7·6	8·6	8·6	7·9	9·1
Principally cloudless.	19 21	42·3	.....	9·3	0·3	.....	.....	9·3
	24 21	34·2	.....	12·7	4·4	.....	.....	12·4
Half-cloudy.	20 21	42·3	.....	3·3	0·3	.....	.....	3·3
	21 21	48·0	.....	9·0	5·2	.....	.....	9·0
	26 21	38·2	4·7	6·2	4·4	4·7	4·2	6·7
Principally cloudy.	27 21	37·4	11·7	9·7	1·1	8·4	5·1	9·4
Cloudy.	28 21	41·8	4·0	5·6	2·3	4·8	3·0	6·6
	29 21	46·0	7·3	8·1	6·2	6·0	7·3	7·3

Table LXXIX.

General state of the sky during the night previous to reading the instruments.	1843. May. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass exposed to $\frac{3}{4}$ths of sky.	On short grass.	On garden mould.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h	°	°	°	°	°	°	°
Cloudless.	1 21	46·3	5·0	8·4	3·0	9·1	5·2	10·5
	10 21	39·9	6·9	11·9	4·9	13·7	10·1	10·4
Principally clear.	2 21	40·7	2·9	7·0	1·7	6·8	4·1	7·7
	6 21	35·4	1·4	1·2	1·4	4·8	3·6	6·4
	7 21	37·3	4·0	1·4	3·7	9·9	8·0	9·3
	11 21	40·3	4·4	10·4	4·4	10·8	9·1	8·8
	14 21	54·5	7·0	7·8	5·9	7·5	7·8	6·9
	25 21	47·3	3·3	3·2	3·0	6·8	6·8	5·8
	28 21	45·2	8·7	4·0	3·0	6·5	7·7	9·0
Half-cloudy.	4 21	47·1	7·3	10·9	3·5	10·1	8·7	4·8
	21 21	44·4	1·9	1·4	2·4	5·4	6·6	5·1
	22 21	48·1	2·7	5·1	3·0	6·4	6·2	5·2
	24 21	48·5	4·5	9·0	8·0	7·3	8·8	5·3
Principally cloudy.	9 21	42·8	3·8	4·3	2·2	8·8	6·9	7·3
	19 21	47·5	7·0	4·3	7·3	.....	7·3	7·7
	26 21	47·3	3·3	4·3	2·3	4·3	3·3	5·8
	27 21	44·8	3·3	4·6	2·2	4·6	5·0	3·0
	29 21	38·5	3·5	3·0	3·3	9·5	9·0	9·2
	31 21	55·3	2·1	1·1	1·5	1·9	2·1	1·5
Cloudy.	3 21	37·3	−2·7	1·3	−4·2	1·3	0·2	−0·2
	5 21	50·2	2·4	0·9	1·4	2·7	2·7	2·0
	8 21	38·0	1·0	−1·0	0·0	1·5	1·2	−4·0
	12 21	51·3	7·5	5·5	6·0	3·3	7·6	2·1
	13 21	45·0	3·0	4·5	−0·5	4·5	3·5	3·8
	15 21	49·4	5·4	2·1	2·4	3·4	3·2	3·7
	16 21	49·3	9·3	6·3	7·3	.....	10·3	5·0
	17 21	44·0	2·0	0·0	1·8	4·0	4·0	4·5
	18 21	44·8	1·7	−0·9	0·7	1·5	2·9	3·8
	20 21	50·3	7·0	7·0	4·1	6·7	9·3	8·6
	23 21	52·6	4·6	6·1	5·8	8·9	9·0	2·8
	30 21	50·3	3·3	1·9	2·2	3·0	3·1	2·8

Table LXXX.

General state of the sky during the night previous to reading the instruments.	1843. June. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass exposed to $\frac{3}{4}$ths of sky.	On short grass.	On garden mould.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h	°	°	°	°	°	°	°
Cloudless.	3 21	47·1	4·3	8·1	3·8	8·6	8·9	8·5
	16 21	48·4	4·9	8·5	3·4	11·3	10·5	10·4
	21 21	53·0	9·0	11·0	8·0	8·0	12·0	13·0
	22 21	44·8	4·8	11·1	4·6	10·8	11·0	10·2
	23 21	50·4	7·2	6·6	5·9	12·9	12·7	12·4
	25 21	45·3	4·6	11·1	4·2	11·6	11·3	8·0
	28 21	43·5	10·2	11·7	7·5	10·5	12·5	9·3
Principally clear.	2 21	51·3	2·3	2·3	1·9	3·0	2·5	3·3
	4 21	42·9	1·5	4·1	1·7	5·4	5·4	5·6
	5 21	43·4	3·6	8·1	3·1	9·9	8·7	7·4
	15 21	51·6	4·4	5·1	3·0	9·6	10·4	11·2
	18 21	50·5	2·5	5·5	1·4	7·5	7·4	5·4
	20 21	44·1	4·1	8·5	3·6	10·8	9·8	10·9
	29 21	52·1	6·3	7·9	5·5	12·0	11·3	9·5
Half-cloudy.	26 21	47·0	3·8	7·3	4·0	10·8	10·6	8·0
Principally cloudy.	1 21	53·5	6·9	11·5	6·3	6·5	10·5	4·4
	6 21	45·2	2·6	3·6	2·2	6·2	5·5	6·0
	8 21	51·2	1·7	2·2	3·0	3·2	2·3	2·7
	9 21	49·1	2·8	3·5	2·9	3·6	3·1	4·3
	10 21	47·8	8·3	5·8	7·8	5·8	6·0	6·3
	11 21	48·8	4·2	5·3	3·6	5·0	6·5	6·7
	24 21	49·8	2·7	1·2	0·3	1·1	2·0	2·3
	27 21	50·2	3·4	1·9	4·2	6·0	6·9	7·2
	30 21	52·3	8·3	8·3	9·5	9·5	11·3	10·1
Cloudy.	7 21	49·9	2·1	1·1	1·2	3·9	1·8	1·4
	12 21	48·8	.....	.....	.....	0·8	.....	2·2
	13 21	51·8	1·3	−1·7	1·8	0·3	1·6	0·8
	14 21	57·0	4·5	5·9	3·6	6·8	7·1	6·4
	17 21	50·6	0·6	1·6	−1·9	3·0	2·1	2·0
	19 21	50·3	3·2	0·6	1·4	.....	3·2	3·3

Table LXXXI.

General state of the sky during the night previous to reading the instruments.	1843. July. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass exposed to ¾ths of sky.	On short grass.	On garden mould.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h							
Cloudless.	4 21	57°·1	10°·6	13°·6	10°·6	11°·3	10°·1	8°·9
	9 21	51·3	4·1	11·8	.....	12·8	9·8	11·3
Principally clear.	2 21	58·6	7·1	8·6	7·6	8·6	8·6	10·1
	7 21	53·4	6·6	5·4	.....	6·2	5·2	6·2
	8 21	47·3	7·3	7·3	.....	7·3	7·3	7·1
	16 21	58·4	4·3	4·3	.....	5·4	4·8	6·3
	17 21	58·1	4·1	4·1	.....	.....	4·4	6·1
	19 21	46·1	6·1	6·1	.....	6·1	6·1	7·1
	23 21	44·6	5·2	5·2	.....	7·4	7·6	9·4
	24 21	46·1	9·6	9·6	.....	9·9	9·9	10·1
	25 21	51·1	4·5	4·5	.....	8·6	8·3	7·5
	29 21	53·5	4·0	4·0	.....	4·0	4·0	5·9
Half-cloudy.	1 21	53·1	2·8	7·1	7·8	4·9	9·5	9·1
	3 21	59·1	2·3	3·1	1·1	3·3	2·6	4·6
	6 21	52·2	3·7	5·2	.....	5·9	5·5	6·8
	14 21	55·4	3·9	10·4	.....	5·4	8·6	5·4
	15 21	57·2	3·3	7·2	.....	6·4	5·0	6·2
	30 21	51·9	5·4	5·4	.....	7·0	6·6	7·9
	31 21	50·1	5·1	5·1	.....	8·1	7·3	6·1
Principally cloudy.	5 21	55·8	3·0	1·8	.....	.....	3·0	3·6
	10 21	54·8	1·2	0·8	.....	5·4	0·8	1·6
	21 21	55·1	4·7	4·7	.....	6·8	6·4	8·1
	22 21	51·7	1·7	1·7	.....	3·7	4·7	1·1
	26 21	57·3	4·8	4·8	.....	5·1	4·8	6·8
	27 21	56·6	4·6	4·6	.....	4·6	4·4	6·4
Cloudy.	11 21	52·8	5·8	1·2	.....	.....	1·8	3·8
	12 21	55·3	1·3	1·1	.....	1·1	0·9	1·8
	18 21	52·3	3·8	3·8	.....	9·6	5·1	7·3
	20 21	54·1	4·0	4·0	.....	4·0	4·1	5·1
	28 21	53·1	0·2	0·2	.....	−0·1	−0·2	1·1

Table LXXXII.

General state of the sky during the night previous to reading the instruments.	1843. August. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of the thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed				
			On long grass exposed to $\frac{3}{4}$ths of sky.	On short grass.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h						
Cloudless.	6 21	48°·7	4°·7	6°·9	7°·2	7°·4	7°·3
	10 21	47·2	6·4	12·2	13·0	13·0	9·4
	11 21	51·0	6·2	9·0	9·1	9·5	9·0
	12 21	49·7	6·7	13·7	12·9	13·3	9·9
	17 21	59·6	6·0	11·0	11·6	11·0	9·0
	18 21	59·0	5·0	11·0	11·0	11·4	10·0
Principally cloudless.	1 21	49·4	2·8	4·5	4·6	4·6	6·5
	5 21	53·6	3·6	4·6	4·6	4·4	6·4
	7 21	60·0	7·0	8·8	9·0	8·0	11·8
	9 21	57·5	6·2	6·8	6·7	6·9	5·0
	13 21	58·6	5·8	8·8	8·4	8·9	10·4
	16 21	56·8	4·8	7·5	7·3	7·4	7·6
	20 21	50·2	4·0	6·6	6·2	6·8	8·2
	21 21	51·0	3·0	6·8	6·8	7·6	9·2
	22 21	49·5	2·8	4·5	4·5	4·7	6·0
	24 21	50·0	5·6	9·7	9·4	10·0	9·8
	26 21	49·2	4·9	8·0	8·1	8·8	7·5
	31 21	56·2	5·4	8·0	8·4	8·5	8·2
Half-cloudy.	3 21	56·0	3·2	9·0	4·0	8·0	5·8
	4 21	52·6	4·5	4·5	5·0	5·0	6·6
	14 21	61·8	6·4	4·0	6·8	4·0	5·8
	15 21	61·8	4·0	7·0	6·8	7·0	7·9
	19 21	62·0	3·9	7·3	7·0	7·5	8·1
	25 21	58·4	1·8	6·0	5·6	6·3	5·9
	27 21	62·0	4·0	3·7	3·7	3·7	5·0
Principally cloudy.	8 21	59·3	3·2	5·6	5·5	5·8	6·1
	30 21	59·5	7·0	8·4	8·2	8·8	8·0
Cloudy.	23 21	53·9	0·7	1·3	1·4	1·2	3·9
	29 21	61·0	2·3	1·2	1·7	2·2	3·8

Table LXXXIII.

General state of the sky during the night previous to reading the instruments.	1843. September. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass exposed to $\frac{3}{4}$ths of sky.	On long grass.	On short grass.	One inch high.	Three inches high.	In focus of metallic reflector.
	d h	°	°	°	°	°	°	°
Cloudless.	2 21	56·8	10·3	.....	8·5	8·5	8·5	7·3
	5 21	48·1	6·1	.....	5·1	7·1	9·1	7·5
	6 21	52·9	5·8	.....	8·9	8·9	8·9	10·5
	9 21	58·0	6·7	.....	11·8	12·3	12·0	11·0
	13 21	50·0	.....	13·8	12·0	8·5	7·0	13·0
	19 21	53·3	.....	12·3	13·3	9·3	5·8	10·8
	20 21	50·6	.....	8·8	7·8	6·6	3·6	6·1
	22 21	50·8	.....	10·8	11·5	8·8	5·2	10·3
	23 21	52·6	.....	11·4	9·5	9·1	5·5	7·8
	24 21	47·4	.....	9·9	10·6	8·1	4·5	8·1
	27 21	38·8	.....	13·0	10·9	9·8	6·3	8·4
Principally cloudless.	4 21	44·3	.....	.....	9·0	9·1	9·8	9·0
	7 21	56·6	7·4	.....	12·4	12·8	12·5	11·6
	12 21	51·8	.....	.....	10·8	10·8	10·9	9·5
	18 21	60·2	.....	8·8	8·0	5·7	3·2	6·7
	26 21	39·5	.....	8·7	8·5	7·3	3·3	7·5
	28 21	36·0	.....	.....	.....	.....	.....	8·4
Half-cloudy.	1 21	58·6	5·3	.....	8·3	8·3	8·8	8·9
	10 21	57·7	4·1	.....	5·7	5·3	6·1	8·6
	15 21	58·0	.....	10·8	9·3	6·0	4·0	7·0
	16 21	54·9	.....	7·2	6·1	3·9	2·8	3·7
	17 21	57·8	.....	8·8	7·3	5·8	3·6	3·8
	21 21	52·0	.....	9·8	10·3	8·8	3·8	9·0
	29 21	47·8	.....	10·4	9·7	7·3	4·8	9·7
Principally cloudy.	11 21	58·7	5·4	.....	5·8	5·2	6·5	10·0
	14 21	61·0	.....	.....	4·2	2·0	4·0	2·5
	28 21	43·4	.....	6·2	5·1	4·7	3·4	7·4
Cloudy.	3 21	57·2	5·7	.....	3·7	4·2	4·6	7·2
	8 21	61·6	4·8	.....	5·4	5·3	5·6	8·6
	30 21	55·8	.....	−0·5	−0·4	−0·2	−0·9	−0·4

Table LXXXIV.

General state of the sky during the night previous to reading the instruments.	1843. October. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed									
			On long grass.	On short grass.	One inch high.	Three inches high.	Six inches high.	In focus of metallic reflector.	On white cotton wool.	On white raw wool.	On coarse flax.	On fine flax.
	d h	°	°	°	°	°	°	°	°	°	°	°
Cloudless.	16 21	32·3	7·8	7·2	5·8	.....	5·2	8·6				
	18 21	28·5	10·0	9·0	8·5	.....	.....	11·0	12·3	14·0	13·0	17·3
	19 21	28·9	8·2	6·9	5·2	.....	.....	5·0	9·1	11·9	11·6	11·1
	21 21	37·5	7·3	5·6	4·5	.....	.....	5·3	7·0	10·0	8·0	9·5
	23 21	47·9	5·1	3·7	2·7	.....	.....	4·7	9·9	13·7	5·7	7·1
	25 21	29·3	7·5	6·3	5·7	.....	.....	6·1	9·3	10·3	10·3	10·8
	26 21	32·3	6·8	4·2	4·2	.....	.....	4·6	6·8	8·5	8·1	7·8
	29 21	40·1	11·2	8·1	6·3	.....	.....	7·6	11·3	13·6	13·4	13·4
Principally cloudless.	3 21	56·3	8·0	6·3	5·3	.....	3·5	4·1				
	5 21	51·3	5·7	5·9	3·3	.....	1·3	4·3				
	9 21	39·1	8·5	8·2	7·1	.....	3·1	5·9				
	12 21	34·9	6·7	5·4	3·7	.....	2·4	6·4				
	14 21	31·0	9·7	9·3	7·5	.....	3·8	10·3				
	15 21	29·7	9·9	9·2	9·3	.....	4·6	10·3				
	22 21	46·3	10·1	8·3	7·6	.....	.....	9·5	9·5	10·1	9·3	10·1
	28 21	34·5	5·7	4·2	3·2	.....	.....	5·7	7·7	7·5	8·5	8·5
Half-cloudy.	1 21	55·8	5·5	5·3	3·8	3·3	.....	5·3				
	2 21	50·0	8·2	8·1	5·9	.....	3·8	8·0				
	4 21	54·3	9·7	8·9	7·8	.....	4·4	7·3				
	6 21	56·9	6·2	5·7	5·9	.....	4·3	4·7				
	17 21	36·5	5·5	3·5	3·0	.....	.....	4·6	6·2	8·0	7·0	6·5
	24 21	46·5	2·9	2·0	2·3	.....	.....	2·3	1·7	2·7	2·6	2·7
Principally cloudy.	7 21	58·0	4·8	3·0	3·0	.....	3·0	2·8				
	13 21	36·6	8·1	6·4	4·9	.....	3·6	6·0				
	27 21	38·5	7·0	2·5	2·5	.....	.....	5·0	6·5	2·5	2·5	2·5
Cloudy.	8 21	48·5	.....	.....	.....	.....	.....	0·9				
	10 21	46·9	0·7	0·9	0·9	.....	1·7	0·7				
	11 21	42·3	7·3	5·0	3·8	.....	2·3	6·4				
	20 21	38·3	3·3	0·6	−0·5	.....	.....	3·8	2·8	6·3	5·9	5·8
	30 21	51·1	6·9	1·8	1·6	.....	.....	1·6				
	31 21	42·5	0·3	0·2	0·0	.....	.....	1·0				

Table LXXXV.

General state of the sky during the night previous to reading the instruments.	1843. Nov. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed							
			On long grass.	On short grass.	One inch high.	In focus of metallic reflector.	On white raw wool.	On white cotton wool.	On fine flax.	On coarse flax.
	d h									
Cloudless.	8 21	29°·8	10°·7	8°·4	6°·3	10°·1	14°·8	13°·8	13°·0	12°·8
	11 21	32·6	10·6	8·4	.....	9·6	15·3	11·6	13·8	15·4
	12 21	27·4	11·5	8·4	.....	8·2	13·9	11·2	12·9	14·2
	13 21	32·3	10·3	8·1	.....	9·1	16·1	10·8	9·9	10·3
	16 21	31·0	8·9	7·8	.....	6·2	.....	.....	9·2	8·9
	29 21	32·9	7·1	6·9	.....	7·6	11·4	.....	10·2	
Principally cloudless.	1 21	35·9	7·3	4·9	3·9	3·9	8·9	8·1	11·7	9·3
	4 21	43·0	7·8	5·2	4·8	6·0	11·0	7·4	9·2	10·8
	6 21	47·4	12·9	3·6	3·2	3·9	6·4	3·4	5·6	5·8
	7 21	41·5	8·5	8·3	5·5	6·3	11·5	9·5	10·5	10·0
	9 21	31·6	8·8	.....	.....	10·1	12·1	11·6	11·6	11·7
	18 21	34·6	5·8	5·4	.....	5·8	5·8	.....	6·2	
	28 21	44·4	10·9	9·6	.....	9·4	11·2	.....	9·2	
Half-cloudy.	3 21	47·8	5·8	4·8	3·8	5·3	9·3	6·8	8·6	8·6
	14 21	30·8	10·8	10·2	.....	9·8				
	19 21	37·9	0·6	.....	.....	4·9	2·9			
	20 21	41·8	4·7	5·5	.....	5·6	6·3	.....	6·1	
	24 21	35·5	5·3	4·8	.....	7·6	8·0	.....	8·0	
	25 21	45·9	5·5	5·3	.....	5·5	9·3	.....	9·3	
	26 21	51·6	3·0	3·2	.....	2·9	3·2	2·9		
Principally cloudy.	26 21	51·6	3·0	3·2	.....	2·9	3·2	.....	3·4	
	27 21	46·7	4·7	4·7	.....	0·1	5·9	.....	5·2	
Cloudy.	2 21	41·2	−1·3	−0·3	0·3	−0·1	0·6	−0·1	0·2	−0·1
	5 21	40·7	6·3	4·0	3·5	3·7	7·7	4·7	6·5	8·5
	15 21	31·6	1·6	0·3	.....	1·8	3·4	1·3	−0·4	0·2
	17 21	37·7	2·5	2·7	.....	2·7	3·5	2·5	3·7	3·1
	21 21	52·6	4·1	4·3	.....	3·6	4·6			
	22 21	44·6	2·4	2·1	.....	2·8	3·5			
	25 21	45·9	−0·3	−4·1	.....	0·1	−0·1	.....	−0·1	
	30 21	45·7	1·6	...	.....	1·2				
Cloudy: cirro-cumulus	10 21	32·6	9·7	7·6	.....	9·5	12·6	12·2	12·3	13·4

Table LXXXVI.

General state of the sky during the night previous to reading the instruments.	1843. Dec. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed						
			On long grass.	On short grass.	On coarse flax.	On white raw wool.	On blackened tin.	On white tin.	In focus of metallic reflector.
Cloudless.	d h None.	°	°	°	°	°	°	°	° .....
Principally cloudless.	2 21	36·5	5·7	4·3	6·5	6·7	4·2	1·7	6·4
	6 21	40·2	5·9	6·2	7·2	7·2	5·4	4·2	7·2
	8 21	33·7	4·9	.....	4·2	7·2	5·5	4·7	5·5
	10 21	39·0	10·2	9·0	10·2	10·0	9·2	8·0	7·2
	17 21	38·5	8·7	9·5	6·7	7·0	5·3	5·7	4·1
Half-cloudy.	5 21	40·1	7·1	6·1	7·3	6·9	5·9	5·9	7·9
Principally cloudy.	1 21	37·6	8·6	8·6	8·3	7·4	8·6	6·8	10·4
	7 21	45·7	6·2	4·7	5·7	6·9	4·2	3·4	3·8
	14 21	39·3	2·5	4·3	3·3	3·5	3·7	2·3	4·3
	15 21	43·1	6·3	4·9	6·3	5·1	4·9	.....	5·1
	24 21	48·4	7·7	6·2	6·0	6·2	4·4	3·2	5·4
	25 21	42·7	8·9	8·3	10·6	10·7	7·8	6·0	7·5
	27 21	42·5	2·9	2·9	2·7	2·5	2·5	2·5	3·5
Cloudy.	3 21	45·3	2·3	3·3	2·0	2·1	.....	.....	3·3
	4 21	45·5	1·9	2·2	1·5	1·7	2·1	2·2	2·8
	9 21	35·1	2·5	−1·9	1·1	0·6	0·8	1·1	2·6
	11 21	30·4	1·1	1·4	2·2	0 3	0·4	0·2	2·9
	12 21	25·6	3·8	3·4	5·3	2·8	4·6	4·3	2·8
	13 21	39·3	6·6	7·8	7·1	8·3	6·5	5·3	2·3
	16 21	44·7	7·5	5·9	5·9	5·6	.....	3·2	5·7
	18 21	42·5	2·5	3·2	3·1	2·4	2·5	2·7	3·7
	19 21	42·3	0·6	0·0	2·0	1·1	1·3	2·3	3·6
	20 21	41·4	3·9	2·4	2·2	1·9	1·9	1·9	3·2
	21 21	41·9	2·9	2·7	2·3	2·2	1·8	2·1	3·9
	22 21	42·5	0·5	1·2	0·9	−0·3	0·3	0·9	2·3
	23 21	49·8	5·6	4·8	5·6	4·2	4·0	3·8	4·5
	26 21	42·5	1·5	2·5	1·5	0·9	1·5	1·9	2·7
	28 21	42·5	1·8	2·0	1·6	1·9	1·2	1·4	2·3
	29 21	38·5	3·2	3·2	3·5	3·3	2·5	2·6	5·2
	30 21	39·3	2·1	2·5	2·8	2·1	2·1	2·5	3·7

Table LXXXVII.

General state of the sky during the night previous to reading the instruments.	1844. January. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed						
			On long grass.	On short grass.	On flax.	On white raw wool.	On blackened tin.	On white tin.	In focus o metallic reflector.
	d h	°	°	°	°	°	°	°	°
Cloudless.	2 21	18·6	8·8	.....	.....	.....	.....	.....	8·3
	15 21	25·4	10·2	9·9	10·6	13·4	9·6	8·9	7·7
Principally cloudless.	7 21	32·2	8·0	7·0	7·2	7·7	7·0	6·2	3·2
	20 21	33·2	9·0	7·2	9·0	12·2	8·0	6·2	6·2
	21 21	39·2	7·4	7·2	9·2	11·2	7·4	6·2	3·6
	22 21	31·4	10·2	8·7	9·5	3·7	9·4	10·1	5·4
	24 21	30·5	8·5	7·5	9·0	11·5	8·5	8·0	6·0
	26 21	35·2	7·0	6·0	7·2	9·3	7·0	6·2	2·2
	28 21	37·3	9·5	8·5	9·4	10·1	8·4	8·1	5·6
Half-cloudy.	6 21	37·8	6·4	5·8	4·8	7·4	6·5	5·1	1·6
	14 21	28·3	7·9	5·7	6·0	10·3	7·3	5·3	7·3
	16 21	27·6	7·0	5·4	6·4	11·9	6·6	5·4	4·6
	18 21	39·2	7·0	6·1	4·2	6·9	7·0	5·4	2·7
	19 21	37·4	8·6	6·6	5·8	9·2	6·7	5·7	3·9
Principally cloudy.	5 21	45·8	5·6	4·5	3·6	3·5	4·8	2·8	1·8
	10 21	36·4	7·7	6·4	5·4	7·4	8·4	8·1	1·9
	11 21	37·7	8·5	8·7	7·9	11·7	9·5	9·3	3·3
	25 21	35·3	4·7	3·5	2·7	3·0	3·5	3·5	1·6
	27 21	40·6	7·3	5·6	6·5	6·2	5·8	5·1	2·1
	29 21	39·7	8·3	8·0	7·1	8·5	7·5	7·4	3·9
	31 21	27·7	5·9	6·4	5·7	8·9	7·2	7·7	3·9
Cloudy.	3 21	22·4	2·9	.....	3·4	3·4	.....	.....	3·4
	8 21	34·2	7·6	6·4	5·6	7·5	7·2	7·2	1·8
	9 21	30·7	1·7	0·9	0·2	1·7	0·9	0·5	0·2
	12 21	39·2	1·8	1·7	1·2	2·4	2·4	1·9	−0·8
	13 21	32·7	1·6	0·9	0·7	1·5	1·7	1·2	−1·8
	17 21	36·5	4·5	4·2	3·3	3·9	4·5	1·7	0·5
	23 21	36·2	4·6	4·2	4·6	5·9	4·9	3·9	2·4
	30 21	32·3	3·3	2·3	1·2	2·7	2·9	2·3	−0·3

Table LXXXVIII.

General state of the sky during the night previous to reading the instruments.	1844. February. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed						
			On long grass.	On short grass.	On flax.	On white raw wool.	On blackened tin.	On white tin.	In focus of metallic reflector.
	d h	°	°	°	°	°	°	°	°
Cloudless.	1 21	27·2	8·6	5·7	6·6	9·0	7·6	8·0	6·4
	15 21	33·0	11·6	8·8	12·0	9·8	9·2	10·9	7·8
	16 21	34·0	7·7	6·5	6·9	6·7	6·0	5·0	6·2
	22 21	22·2	10·4	7·5	10·8	9·8	7·7	7·0	7·7
Principally cloudless.	4 21	29·0	7·5	6·0	6·0	10·2	10·0	10·0	6·0
	6 21	25·4	8·2	6·6	11·6	6·8	8·4	6·6	7·1
	7 21	32·2	5·5	5·0	9·7	6·0	5·2	4·7	3·4
	8 21	32·7	7·1	5·5	5·3	8·7	6·4	6·5	3·6
	19 21	29·7	8·4	6·2	7·8	6·7	5·8	7·0	6·7
	20 21	27·3	8·5	5·3	6·7	9·0	6·3	6·1	6·3
Half-cloudy.	17 21	36·7	7·5	5·3	5·2	3·7	4·7	4·7	4·5
	18 21	40·6	5·4	6·2	4·0	2·8	5·1	1·5	3·8
	24 21	33·4	8·2	5·8	7·2	8·6	6·9	6·4	6·4
	25 21	39·5	6·6	5·2	4·9	3·7	5·5	5·9	3·0
	27 21	29·2	3·8	1·0	4·4	2·7	3·1	2·9	1·2
	28 21	32·2	5·9	3·9	4·2	3·7	5·1	5·6	3·2
Principally cloudy.	6 21	32·0	7·2	5·7	9·0	8·0	6·2	5·7	3·2
	9 21	32·2	2·8	2·8	4·5	3·6	4·4	4·0	1·4
	10 21	31·7	6·5	4·5	4·7	4·7	5·2	4·7	3·9
	12 21	24·5	6·2	3·5	9·6	7·0	4·5	3·7	4·3
	13 21	20·0	6·0	2·0	11·0	12·2	4·0	5·2	3·4
	26 21	27·0	4·9	1·8	5·7	5·4	4·8	4·5	2·6
Cloudy.	2 21	28·0	3·0	2·0	4·0	3·0	6·5	7·0	3·0
	3 21	28·0	2·7	4·3	4·0	3·0	10·0	6·0	2·2
	11 21	30·2	6·0	6·0	4·1	7·2	5·2	4·7	4·7
	14 21	36·8	8·5	7·6	13·8	14·8	7·3	6·8	7·5
	21 21	32·0	0·2	0·3	0·5	−0·2	1·4	0·4	−1·5
	23 21	31·2	4·2	3·2	4·8	3·7	4·4	4·0	5·2
	29 21	38·8	3·0	1·6	4·3	1·5	3·4	3·1	1·8

Table LXXXIX.

General state of the sky during the night previous to reading the instruments.	1844. March. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass.	On short grass.	On flax.	On white raw wool.	On lead.	In focus of metallic reflector.
	d h							
Cloudless.	5 21	24°1	8°9	7°9	14°5	14°9	8°5	12°1
	6 21	30·6	6·8	4·1	4·8	4·6	5·9	5·1
	12 21	31·1	7·1	4·1	5·6	6·8	5·0	4·1
	20 21	27·9	11·4	8·4	18·1	18·9	6·4	8·9
	21 21	32·0	7·2	6·3	12·8	12·4	4·7	5·3
	23 21	33·3	8·3	5·8	9·3	8·3	5·1	4·1
	28 21	34·9	8·7	7·1	13·4	12·6	5·7	5·9
Principally cloudless.	25 21	44·0	6·8	5·6	6·0	7·0	5·8	4·4
	30 21	39·8	6·3	5·5	9·0	8·7	4·5	5·4
Half-cloudy.	1 21	37·1	5·4	4·6	4·0	2·1	5·8	3·1
	3 21	38·6	5·6	3·4	4·6	4·9	4·2	2·1
	7 21	29·6	10·8	6·8	12·0	14·2	8·6	9·4
	10 21	31·7	5·4	3·7	7·7	7·4	4·2	2·7
	11 21	32·8	2·8	2·8	.....	.....	.....	0·0
	13 21	33·7	7·5	5·9	7·6	8·7	5·9	5·5
	17 21	30·3	5·7	4·0	5·5	6·1	4·8	5·1
	24 21	39·5	7·6	5·8	5·8	3·5	6·5	2·0
	29 21	37·9	7·9	5·1	7·9	6·6	2·7	9·3
Principally cloudy.	9 21	40·3	4·3	3·8	7·3	7·3	4·3	1·8
	15 21	36·0	6·6	5·8	6·8	7·9	6·5	5·6
	18 21	36·1	8·1	5·5	8·1	9·1	5·4	5·4
	19 21	39·5	7·3	6·0	6·5	7·2	6·5	4·5
	27 21	42·5	6·5	4·6	8·0	8·5	3·7	3·6
Cloudy.	2 21	35·3	4·3	4·3	4·3	4·3	5·3	2·3
	4 21	32·4	5·9	4·2	5·2	5·6	5·3	5·9
	8 21	36·2	4·6	3·0	3·1	3·8	3·0	3·5
	14 21	38·1	0·5	1·1	2·8	0·9	1·7	−0·2
	16 21	37·5	0·1	0·5	1·1	0·5	0·7	−1·0
	22 21	39·8	1·3	1·1	2·5	1·5	1·1	−1·2
	26 21	46·1	8·1	7·7	9·1	9·1	6·3	4·1
	31 21	37·3	0·6	0·2	2·0	2·4	−0·2	0·7

Table XC.

General state of the sky during the night previous to reading the instruments.	1844. April. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass.	On short grass.	On flax.	On white raw wool.	On lead.	In focus of metallic reflector.
	d h							
Cloudless.	1 21	36·4	7·9	8·4	13·2	11·2	6·7	6·8
	2 21	41·6	12·9	13·4	19·4	17·6	12·9	9·4
	3 21	43·4	13·4	11·4	19·9	18·9	16·4	8·4
	4 21	44·4	11·4	11·1	14·4	14·4	6·9	5·4
	5 21	40·4	11·4	9·2	14·6	13·4	4·6	7·3
	6 21	34·4	10·9	8·9	13·6	12·4	6·4	5·1
	7 21	33·4	11·3	11·8	15·4	16·9	7·9	10·7
	8 21	39·4	10·2	9·9	16·2	15·8	8·4	6·1
	9 21	41·2	11·7	10·7	13·4	13·2	8·7	6·5
	10 21	38·3	13·1	11·6	18·0	16·8	9·5	8·7
	16 21	41·9	10·7	9·7	15·3	15·0	7·8	5·5
	17 21	44·6	11·1	10·6	16·6	15·3	8·6	5·3
	18 21	37·0	12·6	10·1	15·3	14·4	10·0	9·7
	24 21	39 4	14·9	13·6	19·9	20·4	12·4	12·4
	25 21	41·4	13·4	12·6	19·2	17·8	10·4	10·2
	28 21	35·7	11·7	11·4	18·1	15·4	9·5	10·7
	29 21	39·4	10·4	8·7	14·2	12·6	9·0	9·4
	30 21	40·7	12·5	10·5	14·4	14·2	10·2	6·3
Principally cloudless.	19 21	48·2	11·0	10·1	15·1	12·6	12·2	7·0
	22 21	45·1	12·1	10·9	19·1	16·5	13·6	8·3
	23 21	41·4	8·4	6·4	10·4	11·5	6·2	6·2
	27 21	37·1	9·8	9·2	13·4	12·0	8·5	8·1
Half-cloudy.	14 21	43·9	5·7	5·4	8·7	8·6	4·8	3·1
	15 21	48·6	6·6	6·1	8·4	8·5	4·0	4·2
	21 21	43·6	6·4	6·6	9·4	7·6	5·6	2·8
Principally cloudy.	11 21	42·0	10·0	8·8	14·0	14·0	6·8	7·8
	20 21	51·1	8·9	9·0	12·3	10·5	11·1	6·8
Cloudy.	12 21	46·4	2·4	2·5	5·1	6·0	2·1	2·1
	13 21	48·7	4·9	5·1	8·4	7·7	5·3	3·1
	26 21	46·1	0·6	0·1	1·3	2·0	0·4	1·1

Table XCI.

General state of the sky during the night previous to reading the instruments.	1844. May. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed					
			On long grass.	On short grass.	On flax.	On white raw wool.	On lead.	In focus of metallic reflector.
	h h							
Cloudless.	1 21	40°·9	12°·3	12°·3	16°·1	12°·8	10°·9	7°·3
	2 21	40·9	14·7	10·9	17·6	14·6	10·2	9·3
	3 21	48·0	11·8	9·7	12·0	13·0	7·8	7·8
	6 21	44·6	11·6	10·6	14·1	13·1	.....	9·1
	8 21	49·6	9·8	12·4	13·6	12·4	.....	8·6
	10 21	45·2	13·5	12·2	13·4	12·9	.....	7·7
	15 21	44·6	15·6	13·6	16·4	9·4	9·3	12·8
	23 21	44·2	7·5	6·1	10·8	10·3	.....	4·5
	25 21	40·6	9·4	9·1	11·1	11·4	.....	7·1
	27 21	42·1	6·8	9·4	6·9	9·1	.....	6·3
Principally cloudless.	5 21	44·6	9·6	11·6	11·9	11·4	9·3	4·2
	13 21	46·8	12·8	11·8	14·0	16·8	.....	7·8
	17 21	33·9	7·4	6·1	5·7	13·9	.....	6·9
	19 21	43·2	13·2	12·2	.....	.....	.....	6·4
	20 21	43·8	6·0	5·8	5·9	3·3	1·0	4·9
Half-cloudy.	7 21	46·7	11·7	10·7	.....	.....	.....	8·2
	12 21	44·4	8·4	7·4	.....	.....	.....	5·6
	16 21	44·4	12·4	10·4	14·5	14·5	7·4	8·4
	18 21	39·7	7·1	7·7	11·5	11·7	5·7	7·5
	21 21	37·4	2·4	1·3	2·3	2·4	0·5	−2·0
	26 21	42·0	8·7	8·5	.....	.....	.....	7·8
Principally cloudy.	24 21	46·2	5·2	4·7	8·7	8·7	.....	−1·3
Cloudy.	4 21	48·4	2·4	1·4	.....	.....	.....	−1·6
	9 21	51·7	10·7	9·9	9·4	9·3	.....	11·4
	11 21	51·4	3·4	2·4	.....	.....	.....	2·2
	14 21	42·4	9·4	8·4	.....	.....	.....	5·4
	22 21	47·4	0·2	0·0	.....	.....	.....	0·4
	28 21	46·8	3·3	4·3	4·1	4·8	.....	3·5
	29 21	45·2	5·2	5·7	.....	.....	.....	2·4
	30 21	45·9	3·4	3·8	4·6	4·9	.....	3·4
	31 21	44·5	11·9	12·5	15·5	15·7	.....	9·8

Table XCII.

General state of the sky during the night previous to reading the instruments.	1844. June. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed				
			On long grass.	On short grass.	On flax.	On white raw wool.	In focus of metallic reflector.
	d h	°	°	°	°	°	°
Cloudless.	10 21	48·1	10·8	10·1	9·5	9·6	5·1
	13 21	53·0	8·6	8·8	7·0	9·0	7·0
	16 21	47·1	10·9	9·4	5·7	5·6	2·5
	22 21	54·0	11·2	10·1	.....	.....	10·0
	23 21	63·1	12·2	7·1	9·1	9·1	6·6
	30 21	52·5	11·4	10·4	.....	.....	9·2
Principally cloudless.	1 21	44·1	8·1	8·1	10·1	9·3	7·9
	4 21	48·6	9·6	11·6	12·9	13·6	9·1
	8 21	52·8	10·5	11·2	12·3	.....	8·3
	14 21	49·2	7·9	7·0	7·2	7·9	6·0
	21 21	57·3	8·1	7·2	9·5	10·4	7·4
Half-cloudy.	3 21	48·8	10·8	10·8	.....	.....	7·9
	7 21	52·4	8·4	7·6	8·9	.....	4·6
	9 21	51·3	6·5	6·1	6·5	.....	4·8
	11 21	49·5	6·0	5·5	.....	.....	3·5
	17 21	53·9	10·7	11·5	6·9	8·8	4·1
	20 21	52·9	3·7	4·6	4·2	6·9	3·4
	29 21	58·9	7·9	7·1	.....	.....	6·9
Principally cloudy.	2 21	44·5	12·5	12·0	.....	.....	9·3
	5 21	54·2	6·6	6·2	8·4	6·4	5·0
	6 21	54·6	4·6	5·4	5·7	6·6	3·0
	12 21	52·7	7·4	6·3	7·2	8·9	0·2
	15 21	46·9	12·3	11·5	.....	.....	9·5
	18 21	52·5	9·7	8·2	10·3	11·2	7·3
	19 21	47·9	5·9	5·9	7·9	7·9	5·1
	24 21	58·9	6·8	6·0	7·9	7·9	1·9
	27 21	51·7	12·7	8·9	12·5	12·7	10·6
	28 21	49·9	8·1	8·2	12·1	11·6	8·1
Cloudy.	25 21	47·7	1·4	1·6	2·4	1·7	3·5
	26 21	52·9	1·9	1·6	2·6	1·9	3·9

Table XCIII.

General state of the sky during the night previous to reading the instruments.	1844. July. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed				
			On long grass.	On short grass.	On flax.	On white raw wool.	In focus of metallic reflector.
	d h	°	°	°	°	°	°
Cloudless.	13 21	59·0	8·0	6·0	.....	.....	6·5
	14 21	51·2	8·2	6·2	.....	.....	6·7
	15 21	54·5	14·2	12·8	16·8	11·5	12·9
	16 21	47·1	7·8	6·8	9·1	9·6	4·9
	18 21	47·3	11·8	10·3	16·1	13·3	7·3
	19 21	48·0	9·7	10·1	13·8	14·2	7·4
	20 21	49·5	10·0	8·5	12·0	12·0	7·5
	22 21	57·3	12·1	10·3	14·1	14·1	11·3
	23 21	60·2	10·2	8·6	11·4	11·9	7·7
	24 21	57·0	14·7	10·2	12·9	13·1	8·5
	27 21	53·3	10·3	8·2	11·3	11·3	7·3
	29 21	49·3	13·3	11·3	.....	.....	10·0
Principally cloudless.	21 21	53·8	8·8	10·0	13·1	12·9	7·1
Half-cloudy.	5 21	51·1	8·6	6·1	9·9	10·0	7·0
	7 21	55·0	8·0	7·2	.....	.....	3·7
	8 21	57·1	5·3	5·2	3·5	6·3	4·8
	9 21	51·7	9·2	8·7	11·5	7·9	7·9
	26 21	57·9	17·3	.....	.....	.....	7·9
Principally cloudy.	1 21	55·0	8·0	7·0	8·0	8·0	3·4
	3 21	54·6	7·6	7·0	8·1	8·1	5·0
	4 21	55·5	6·5	6·0	.....	.....	3·5
	11 21	56·2	5·2	4·9	5·2	5·2	4·4
	12 21	54·2	7·2	6·2	7·2	7·2	3·2
	17 21	54·5	4·5	3·5	5·3	4·5	6·5
	25 21	62·0	15·3	15·4	12·5	19·0	5·5
	28 21	58·1	8·1	7·1	.....	.....	3·8
	31 21	48·7	5·2	7·7	7·7	7·7	7·7
Cloudy.	2 21	52·5	3·9	2·4	3·5	2·9	2·9
	6 21	55·0	2·8	2·0	3·8	3·8	3·2
	10 21	60·5	3·5	2·0	.....	.....	1·5
	30 21	56·8	2·7	2·3	3·5	3·3	5·0

Table XCIV.

General state of the sky during the night previous to reading the instruments.	1844. August. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed				
			On long grass.	On short grass.	On flax.	On white raw wool.	In focus of metallic reflector.
	d h						
Cloudless.	1 21	45·6	7·9	5·5	7·1	6·8	6·6
	2 21	52·8	11·3	9·8	11·3	12·6	8·2
	7 21	50·9	4·3	5·6	6·7	6·5	7·3
	8 21	49·2	6·2	6·7	8·6	8·7	7·4
	13 21	52·8	11·6	5·3	6·6	6·3	4·1
	14 21	49·0	8·0	5·5	8·5	8·0	4·9
	18 21	45·4	8·6	6·9	8·4	11·1	6·7
	27 21	42·8	11·0	10·0	12·0	.....	8·0
	28 21	44·6	9·3	8·8	12·5	.....	7·8
	29 21	46·8	10·0	10·1	13·9	.....	9·5
	30 21	46·2	10·5	9·3	11·9	.....	7·5
	31 21	46·3	8·5	7·8	10·6	.....	6·7
Principally cloudless.	4 21	49·7	9·5	5·3	7·7	8·4	9·4
	6 21	52·3	6·3	5·3	5·3	6·3	6·5
	15 21	50·3	7·7	4·8	7·4	6·8	7·8
	17 21	47·3	7·1	6·1	9·6	7·1	6·9
	22 21	48·2	8·3	6·4	9·4	8·5	6·7
	23 21	47·5	9·7	8·3	10·5	11·7	7·8
Half-cloudy.	3 21	54·2	4·6	4·5	16·6	14·0	7·2
	9 21	47·8	7·8	6·3	7·8	7·8	8·6
	10 21	45·3	11·1	8·1	12·3	11·3	8·8
	16 21	57·2	.....	.....	.....	.....	5·4
	26 21	51·2	10·0	6·7	10·9	.....	7·7
Principally cloudy.	20 21	51·6	6·4	5·3	5·9	5·8	7·9
Cloudy.	5 21	57·8	10·8	11·6	11·6	13·6	3·3
	11 21	56·2	4·2	4·2	.....	.....	3·7
	12 21	54·5	3·2	3·0	4·8	5·8	5·4
	19 21	57·7	0·9	0·7	0·9	1·0	1·1
	21 21	52·8	3·0	2·6	6·0	3·5	3·8
	24 21	52·3	7·6	5·8	7·3	8·5	6·5
	25 21	52·4	4·4	3·2	5·3	.....	9·1

Table XCV.

General state of the sky during the night previous to reading the instruments.	1844. September. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed			
			On long grass.	On short grass.	On flax.	In focus of metallic reflector.
	d h					
Cloudless.	1 21	48°·7	11°·9	11°·2	14°·4	12°·2
	4 21	59·4	6·3	5·9	8·1	7·9
	10 21	44·8	10·8	10·0	12·8	11·3
	18 21	41·3	11·3	8·3	11·3	7·8
	19 21	47·3	11·5	9·6	13·6	13·7
	20 21	45·9	11·1	10·9	14·6	10·1
	24 21	41·8	11·5	9·6	11·8	9·6
	25 21	40·8	10·5	8·4	12·6	9·6
	26 21	41·1	11·1	8·5	14·9	9·5
	27 21	40·3	9·9	6·1	.....	8·1
	28 21	45·1	9·8	8·1	.....	8·5
	29 21	34·8	9·8	7·3	12·2	7·6
Principally cloudless.	2 21	51·0	10·5	9·5	13·7	8·4
	5 21	57·0	10·0	9·7	12·4	8·3
	11 21	49·8	9·6	8·3	10·6	10·0
	21 21	47·1	10·6	10·1	13·1	11·1
	22 21	49·1	13·1	12·1	.....	5·1
Half-cloudy.	6 21	62·6	.....	.....	.....	16·2
	7 21	56·8	6·3	5·6	8·7	7·8
Principally cloudy.	12 21	52·9	7·5	5·7	8·6	8·2
	13 21	53·8	6·8	6·4	7·5	8·1
	16 21	60·8	5·4	4·6	6·5	5·0
	17 21	53·9	5·3	5·2	7·8	2·3
	23 21	49·3	7·0	3·9	7·4	8·1
Cloudy.	3 21	59·6	3·8	3·1	4·2	3·4
	8 21	55·5	3·2	1·5	3·2	6·0
	9 21	55·8	0·8	1·1	0·8	5·8
	14 21	57·3	4·8	4·4	4·9	6·0
	15 21	61·4	4·1	4·6	4·8	5·9
	30 21	42·2	1·6	2·6	2·9	

Table XCVI.

General state of the sky during the night previous to reading the instruments.	1844. October. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air, at the height of 4 feet and protected from the effects of radiation, above that placed			
			On long grass.	On short grass.	On flax.	In focus of metallic reflector.
	d h					
Cloudless.	3 21	53°·3	18°·8	17°·8	21°·8	13°·7
	7 21	33·2	10·2	8·7	19·5	4·2
	10 21	47·2	7·7	7·2	8·6	3·2
	18 21	36·5	6·7	5·3	7·5	4·2
	22 21	30·8	6·5	4·6	7·3	5·3
	26 21	43·2	12·5	9·0	13·7	7·4
	27 21	36·2	12·0	9·7	9·9	5·5
	30 21	40·8	11·0	7·6	10·6	5·6
Principally cloudless.	4 21	53·8	13·0	12·0	14·8	8·5
	5 21	44·0	10·2	9·0	13·0	3·5
	11 21	46·8	7·8	7·3	9·5	4·6
	14 21	47·5	6·4	5·5	8·0	7·0
	28 21	39·8	11·4	9·4	10·1	10·2
	31 21	44·2	8·2	5·5	7·0	6·7
Half-cloudy.	2 21	51·0	9·0	8·4	12·0	6·0
	6 21	44·1	8·7	8·1	8·1	4·0
	8 21	45·7	8·5	7·7	8·2	5·7
	13 21	49·2	7·9	6·2	12·2	7·2
	16 21	42·2	6·2	5·5	7·7	4·7
	17 21	39·8	5·4	4·5	7·8	8·3
Principally cloudy.	19 21	45·3	5·6	5·8	8·8	6·3
Cloudy.	1 21	57·6	5·1	4·6	5·6	3·2
	9 21	53·6	4·8	4·1	6·6	3·3
	12 21	55·8	5·7	6·0	9·8	3·6
	15 21	46·7	2·0	1·7	2·2	2·9
	20 21	44·5	10·0	6·4	11·5	7·9
	21 21	43·2	3·2	1·3	1·2	3·2
	23 21	35·5	7·7	9·7	13·3	5·0
	24 21	47·2	1·1	0·5	1·9	2·7
	25 21	43·1	9·1	5·5	16·1	7·9
	29 21	42·7	3·7	2·4	2·7	7·7

Table XCVII.

General state of the sky during the night previous to reading the instruments.	1844. November. Day and hour of reading.	Reading of thermometer in air at the height of 4 feet.	Excess of the reading of a thermometer in air. at the height of 4 feet and protected from the effects of radiation, above that placed			
			On long grass.	On short grass.	On flax.	In focus of metallic reflector.
	d h	°	°	°	°	°
Cloudless.	15 21	48·3	9·9	5·0	7·6	6·1
	20 21	34·8	10·3	5·8	11·8	5·8
Principally cloudless.	4 21	34·6	9·0	7·6	6·6	9·6
	13 21	43·4	10·8	8·9	9·4	6·4
	21 21	34·3	10·8	7·3	10·9	8·8
	23 21	33·5	11·0	8·8	11·5	9·5
	26 21	27·4	8·1	5·6	9·4	7·2
	27 21	29·5	7·5	4·8	9·5	5·0
	30 21	31·9	10·2	8·4	13·4	10·5
Half-cloudy.	6 21	38·3	9·3	7·6	8·3	7·3
	8 21	47·3	8·3	7·4	8·3	7·6
	9 21	38·3	4·9	4·6	7·0	6·3
	10 21	41·0	7·5	6·4	7·5	7·7
	24 21	36·6	9·4	6·0	10·7	8·6
	25 21	32·1	8·7	6·4	11·4	7·8
Principally cloudy.	3 21	36·8	7·0	4·0	6·1	8·0
	11 21	40·3	6·0	3·0	6·8	4·8
	16 21	49·0	5·0	4·4	6·4	4·2
Cloudy.	1 21	41·0	0·4	0·2	0·3	2·0
	2 21	37·0	1·0	0·1	0·5	2·5
	5 21	39·1	5·1	2·6	4·1	2·2
	7 21	43·9	3·4	2·6	3·1	4·6
	12 21	48·8	0·8	0·9	−0·1	1·8
	14 21	47·6	5·2	5·2	1·8	2·8
	17 21	48·7	0·8	0·6	0·6	2·7
	18 21	49·5	2·0	1·3	1·4	2·5
	19 21	46·4	2·9	1·9	1·1	4·5
	22 21	36·4	10·0	8·7	11·1	2·2
	28 21	35·5	3·8	3·0	3·5	4·6
	29 21	37·6	3·5	3·4	2·6	

Table XLVIII.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From Tables LI. to XCVIII. we learn the following particulars. As the series of observations of the thermometer whose bulb was placed in the focus of the parabolic reflector extends over a much longer period of time than any of the others, it is desirable to discuss the results derived from it before consulting those deduced from the observations of the other instruments. Confining ourselves therefore to the numbers found from the observations of the thermometer in the reflector; first, to those in that division of every table under cloudy nights, it will be seen that during such nights its reading has frequently been higher than that in air, but it has generally been from 0° to 3° lower; frequently 4°; less frequently from 5° to 8°, and occasionally 9° less than that in air. In Tables LXXII., LXXIV. and LXXV., quantities equal to 9° are exhibited; and in the last-mentioned table there is one case of 13°·3; in Table XCI. there is one case of 11°·4; during the nights that these large differences have occurred the clouds have been noted as being fleecy, thin and high. In Table LXXXV. large differences are exhibited; the sky was noted at the time as being covered with cirrocumuli.

As the results on those nights during which more or less cloud prevailed are generally between those on cloudy and on cloudless nights, and nearly proportional to the amount of cloud; the next division of these tables, which deserves particular attention, is that containing the results derived from cloudless nights. By examining the numbers in this division, it will be found that quantities less than 5° have taken place, even on cloudless nights. The atmosphere, however, on such nights has been noticed as being thick, and the air as being saturated with moisture. The following is a list of these cases:—

The result deduced from the observation taken in the year	1841, on March 10, at 21^{h}.
	1841, on March 29, at 21.
	1841, on June 20, at 21.
	1841, on July 9, at 21.
	1841, on September 6, at 21.
	1841, on November 19, at 21.
	1842, on April 8, at 21.
	1842, on August 3, at 21.
	1842, on August 16, at 21.
	1842, on August 17, at 21.
	1842, on August 28, at 21.
	1842, on December 5, at 21.
	1843, on October 26, at 21.
	1843, on December 17, at 21.
	1844, on March 12, at 21.
	1844, on March 23, at 21.
	1844, on May 20, at 21.
	1844, on June 16, at 21.

The result deduced from the observation taken in the year . . . . . { 1844, on July 16, at 21h. / 1844, on August 13, at 21. / 1844, on August 14, at 21. / 1844, on October 7, 21. / 1844, on October 10, at 21. / 1844, on October 18, at 21.

In all twenty-five instances out of 331 cloudless nights; on one of these nights, viz. that preceding 1842, August 28, 21h the result was a reading of 0°·6 higher than that of the thermometer in air, but it is very probable that the reading was in error.

The general amount on cloudless nights is from 7° to 10°; and frequently above 10°. During the four years' observations there were thirty-three cases in which the reading of the thermometer in air exceeded that of the thermometer in the reflector by quantities between 10° and 11°; there were nineteen cases between 11° and 12°; sixteen between 12° and 13°; eight between 13° and 14°; and there were four instances in which the excess amounted to 14° and was less than 15°; these cases occurred during the nights preceding 1842, June 16, 21h and October 29, 21h; 1843, February 12, 21h and March 6, 21h. (The differences in 1843 March were unusually large.) There were two cases exceeding 15°, both in 1842 on June 6 and 7; and there is one above 17° which occurred during the night preceding 1843 March 2, 21h. This is the largest difference shown during the four years' observations, between the thermometer in the air and that in the reflector. I now proceed to speak of the results derived from the observations of the other instruments.

Those from cloudy nights with all the other thermometers were nearly the same as those with the thermometer with its bulb placed in the focus of the reflector, excepting that their readings were much less frequently higher than those of the thermometer in air than were those of that instrument.

On partially cloudy, and on cloudless nights, the reading of the thermometers on grass, those placed one inch above it, those on raw wool and flax, were always much lower than that in the reflector; and frequently, even on grass, the reading was as much below that in the reflector as the latter was below that in the air; on wool and flax it was nearly always so.

The greatest difference between the readings of that in air and that on short grass was 17°·8; and on long grass was 18°·8; and they took place during the night preceding 1844, October 3d 21h (see Table XCVI.). The reading of the thermometers which were placed on wool and flax were frequently from 15° to 18°, and occasionally from 19° to 21° less than that in air. The greatest difference with raw wool was 20°·4; and with flax was 21°·8, as observed 1844, April 24d at 21h, and on October 3d at 21h respectively.

The readings of the thermometer placed on garden mould were always (excepting when the sky was quite cloudy) nearer to that in the air than any of the other

readings mentioned in this section; and this reading was nearer and nearer to that in the air in proportion to the looseness of the mould; the heat from beneath passing the more rapidly to the surface in proportion to its looseness. It was also observed that the temperature about the roots of plants was lower in exact amount to the excess of heat conducted to the surface.

It must be borne in mind that the differences exhibited between the minimum readings of self-registering thermometers placed upon substances and fully exposed to the sky, and those of a similar thermometer placed in the air, and protected as much as possible from the sky, are not the maximum differences, unless the two minima occur at the same time; this generally is not the case; that of a thermometer placed on any substance and exposed to the sky usually occurs in the evening, or before midnight; whilst that in the air occurs at about the time of the rising of the sun. The difference between these two minima should be increased by the difference between the readings of the thermometer in the air at those times; this may amount to 10°; and it is highly probable that during a portion of the evening or night, which precedes the reading of the instruments, at times when 20° are exhibited between the minima, a difference of 30° has existed.

From the preceding remarks it is evident that the differences between the readings of the thermometer in air and the others, have varied with every variation of the amount of cloud; and by comparing the numbers in one table with those in another, it will be found that this difference is about the same in amount, with the same quantity of cloud at all times of the year.

This will be more clearly seen in the next table containing the monthly means of all the numbers contained in Tables LI. to XCVIII. of the results of the observations of the thermometer in the reflector.

Table XCIX.—Mean Monthly excess of the readings of the thermometer in Air above that in the Reflector.

General state of the sky during the night previous to reading the instruments.	Month.	The mean monthly excess, according to the state of the sky with respect to the quantity of cloud, of the readings of a self-registering thermometer placed in air at the height of 4 feet and protected from radiation, above those of a similar thermometer placed in the focus of a metallic parabolic reflector.										
		1841.		1842.		1843.		1844.		1841 Feb. 11, to 1844 Dec. 31.		
		Mean excess.	No. of nights.	Mean excess.	No. of nights.	Mean excess.	No. of nights.	Mean excess.	No. of nights.	No. of nights.	Sum of excess.	Mean excess.
Cloudless.	January.	.....	.....	0.4	4	0.6	4	0.4	4	20	24.1	1.2
	February.	0.4	1	0.4	4	0.3	3	0.2	2	10	6.2	0.6
	March.	0.5	12	0.5	4	0.4	5	0.5	5	26	18.2	0.7
	April.	0.6	7	0.7	4	0.4	2	0.4	4	17	11.9	0.7
	May.	0.5	7	0.5	4	0.4	2	0.4	4	17	9.7	0.6
	June.	0.4	8	0.4	3	0.4	3	0.4	4	18	9.7	0.5
	July.	0.6	8	0.4	4	0.4	2	0.4	4	18	9.7	0.5
	August.	0.5	6	0.5	3	0.6	4	0.5	4	17	9.7	0.6
	September.	0.4	6	0.5	5	0.5	4	0.5	4	19	11.2	0.6
	October.	0.5	5	0.6	4	0.5	4	0.5	4	17	11.2	0.7
	November.	0.4	5	0.4	4	0.4	4	0.4	4	17	9.7	0.6
	December.	0.4	4	0.4	4	.....	4	0.4	4	16	8.8	0.6
Principally cloudless.	January.	.....	.....	0.3	4	0.3	4	0.3	4	21	8.6	0.4
	February.	.....	0	0.4	4	0.3	4	0.3	4	21	8.6	0.4
	March.	0.3	5	0.4	4	0.4	4	0.3	4	21	10.0	0.5
	April.	0.4	4	0.4	4	0.4	4	0.3	4	20	9.6	0.5
	May.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	June.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	July.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	August.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	September.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	October.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	November.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	December.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
Half-cloudy.	January.	.....	.....	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	February.	0.4	0	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	March.	0.4	5	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	April.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	May.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	June.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	July.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	August.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	September.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	October.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	November.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	December.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
Principally cloudy.	January.	.....	.....	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	February.	0.4	0	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	March.	0.4	5	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	April.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	May.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	June.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	July.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	August.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	September.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	October.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	November.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	December.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
Cloudy.	January.	.....	.....	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	February.	0.4	0	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	March.	0.4	5	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	April.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	May.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	June.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	July.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	August.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	September.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	October.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	November.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5
	December.	0.4	4	0.4	4	0.4	4	0.4	4	20	9.6	0.5

The numbers contained in this table show very clearly that, under the same state of the sky, the excess of the reading of the thermometer in air above that in the reflector is the same at all times of the year, and they as clearly show that the amount of the excess varies with every variation of the quantity of cloud. These results are exhibited in each year; and they are very decidedly shown in the last column of each division of the table, which contains the mean results for every month derived from the four years' observations, excepting in January, which was deduced from three years only.

Table C. is formed from the numbers in Table XCIX. by taking their yearly values for each state of the sky. The last column of this table contains the mean result from all the observations which were spread over 1419 nights; in the year 1841 there was one observation lost; in 1842 there were fifteen; in 1843 there were nine, and in 1844 there were six. These observations were lost chiefly from the instrument being out of repair, or the having omitted to set the index the previous day. The result in the last column is therefore deduced from 1389 nights, and include those from all states of the sky and weather.

TABLE C.—Showing the mean results in each year, with the different states of the sky, and for the whole time derived from all the self-registering observations of the thermometer whose bulb was placed in the focus of a metallic parabolic reflector.

State of the sky.	The mean yearly excess, according to the state of the sky with respect to the quantity of cloud, of the readings of a self-registering thermometer placed in air at the height of 4 feet and protected from radiation, above those of a similar thermometer placed in the focus of a metallic parabolic reflector fully exposed to the sky.																
	1841.			1842.			1843.			1844.			1840 February 10, to 1844 December 31.				
	Whole sum of excesses.	Whole number of nights.	Mean excess.	Whole sum of excesses.	Whole number of nights.	Mean excess.	Whole sum of excesses.	Whole number of nights.	Mean excess.	Whole sum of excesses.	Whole number of nights.	Mean excess.	Whole number of nights.	Sum of excesses.	Mean excess.	Whole number of nights.	Sum of excesses.	Mean excess per night.
Cloudy	97°3	66	1°47	177°8	72	2°47	281°4	86	3°27	322°9	97	3°33	321	879°4	2°74		°	°
Principally cloudy...	203·9	70	2·91	118·8	30	3·96	258·2	49	5·27	237·4	49	4·85	198	818·3	4·13			
Half-cloudy..	396·0	78	5·08	430·5	82	5·25	394·9	62	6·37	336·4	60	5·60	282	1557·8	5·52	1389	7826·4	5·65
Principally clear ...	270·8	43	6·30	578·4	81	7·14	591·1	78	7·58	374·4	55	6·81	257	1814·7	7·06			
Cloudless ...	535·9	66	8·12	682·1	85	8·03	768·1	81	9·48	770·1	99	7·78	331	2756·2	8·33			

By considering that the cloudy nights in this table are represented by 10; the principally cloudy by 8; the half-cloudy by 5; the principally clear by 2; and the cloudless by 0, the following particulars may be deduced from this table.

The sum of the products of the above numbers into the number of nights of each class in each year, divided by the number of nights in the year, gives the mean state of cloudiness during the nights of that year; and the yearly sum of the excess of the reading of the thermometer in air above that placed in the reflector, divided by the number of nights in the year, gives the excess, corresponding to the mean state of cloudiness; and thus we find

In the year 1841	The mean state of cloudiness during the nights was	. .	5·8,	and the mean excess of the reading of the thermometer in the air above that in the reflector was	. .	4·7
In the year 1842	„	. .	4·4,	„	. .	5·7
In the year 1843	„	. .	4·9,	„	. .	6·4
In the year 1844	„	. .	5·0,	„	. .	5·7

And the mean state of cloudiness during the nights of the four years was 5 (or the sky upon the average had been one-half covered by cloud), and the corresponding mean excess of the reading of the thermometer in air above that in the reflector was 5°·65.

In the year 1841 the number of clear and cloudy nights were equal; and they were nearly the same in number in the year 1844; in the year 1842 the number of clear nights exceeded the number of cloudy nights by thirteen; and in 1843 the cloudy exceeded the clear nights by five: from this it appears that during these four years there were one clear and one cloudy night out of every four nights.

In Table XLV. the relative less reading of a thermometer placed on raw wool and one in the focus of a parabolic reflector, than that in the air was found to be as 1221 : 888 from 889 simultaneous observations.

In Table CVI. this ratio is found to be as 1280 : 962 from 992 observations, deduced from self-registering minimum thermometers. As these results are so nearly identical, and as they have been deduced by entirely different instruments, there can be but little doubt of the correctness of their mean, viz. 1251 : 910, or in other words, the results as derived from the observations of the thermometer in the reflector, would be converted into results as deduced from placing a thermometer on raw wool by multiplying the former by 1·375, and in this way we should derive 7°·76 (*i. e.* 5°·65 × 1·375) as the mean deduced from the four years' observations; and we should find 11°·5 (*i. e.* 8°·33 × 1·375) as that deduced from cloudless nights. I have preferred exhibiting these results in terms of that derived from raw wool in consequence of it being free from the effects of heat conducted from the earth, and therefore free from one of the many sources from which the reading of a thermometer placed on the ground is affected, some of which are as follows:—

From the heat of the earth upon which it is placed.

From the heat radiated to it from lateral objects.

From the heat communicated to the substance from the air in contact with it.

From the heat evolved during the change of the watery vapour in the atmosphere into dew.

From the heat received from the radiation from clouds.

From the heat received from the upper regions of the atmosphere, and

From the heat received from space.

By placing a thermometer on wool the effect of the first of these causes is evaded, as appears in a previous section; in a wide and open plain the second would be evaded, as there would be but few objects to emit heat; I fear, however, that all my

readings are affected from this cause, and to an unknown amount; the heat of the air is known, and therefore it can be accounted for; the amount of heat evolved during the change of vapour into water appears to be about 4° from all the experiments I have made; the heat radiated from dense clouds, near the earth, must be very nearly the same in amount as that radiated from the earth, as the clouds when at a low elevation must possess very nearly the same heat as that of the lower atmosphere; but when such clouds are high their temperature must be less than when at a low elevation, and they will radiate less heat to the earth than they will receive from it (see the following experiments upon the different results deduced from high and low clouds, of the same modification and covering the same extent of sky); and the amount of heat from the other sources is unknown. The whole effect of all these checks upon the production of a great cold at night, by the radiation of heat from bodies on the surface of the earth, cannot be estimated, yet, notwithstanding their operation, the reading of a thermometer placed on the ground has been frequently very low. The reading of a thermometer thus placed represents the amount of heat received from all the above sources, diminished by the amount radiated from itself.

The place in which the observations were taken is not favourably situated for the production of a great cold, from radiation of heat at night, it being surrounded, at no great distance, by large trees, and consequently the humidity of the atmosphere is great.

From the circumstance of low readings always having taken place when the sky has been cloudless and bright, we may readily infer that the temperature of space must be very low indeed.

The reading of a thermometer placed on grass is much affected by the heat conducted to it from the earth beneath; yet, notwithstanding, its readings were always less than those of the thermometer in the reflector, in the ratio of 1000 : 858 (see Table XLV.), therefore it is necessary to multiply the results derived from the latter by 1·17 to reduce them to results that would have been derived from the former.

By examining the numbers in the columns under the lowest thermometrical readings in Table CVII., it appears that long grass, and therefore vegetation is liable to be affected at night from the influence of radiation by a temperature below the freezing-point of water every month in the year, for even in July 1844, the only exception in that year, the thermometer read 35°·5, whilst that in the reflector read 39°·3; in the year 1843, in July, the reading in the reflector was as low as 35°·2, and it seems very probable that long grass temperature at this time was at or below 32°; and as all the readings would have been lower if the experiments had been made in the open country, it seems certain that vegetation is always liable to the temperature of 32° in this country.

The next table is formed by taking the means of all the numbers contained in each division of the Tables LXXVIII. to XCVIII.

Table CI.—Showing the mean monthly excess of the reading of a self-registering minimum thermometer in Air at the height of 4 feet, above the

General state of the sky during the night previous to reading the instruments.	Year.	Month.	The mean excess in each month, according to the state of the sky with respect to the quantity of cloud, of the readings of a self-registering minimum thermometer placed in air at the height of 4 feet and protected.											
			On long grass exposed to 9ths of the sky.		On long grass.		On short grass.		On garden mould.		In air one inch high.		In air three inches high.	
			Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.
Cloudless.	1843.	April.	8·1	1	…	…	8·5	1	5·6	3	8·6	1	7·9	1
		May.	6·0	2	…	…	10·2	2	4·0	2	11·4	2	7·7	2
		June.	6·5	7	…	…	9·7	7	5·5	7	10·5	7	11·3	7
		July.	7·4	2	…	…	12·7	2	10·0	1	12·0	2	10·0	2
		August.	5·8	6	…	…	10·6	6	…	…	10·8	6	10·9	6
		September.	7·1	4	11·4	7	10·0	11	…	…	8·8	11	6·9	11
		October.	…	…	8·0	8	6·4	8	…	…	5·3	8	…	…
		November.	…	…	9·9	6	8·0	6	…	…	6·3	1	…	…
		December.	…	…	…	0	…	0	…	…	…	0	…	…
	1844.	January.	…	…	9·5	2	9·9	1	…	…	…	…	…	…
		February.	…	…	9·6	4	7·1	4	…	…	…	…	…	…
		March.	…	…	8·3	7	6·2	7	…	…	…	…	…	…
		April.	…	…	11·8	18	10·7	18	…	…	…	…	…	…
		May.	…	…	11·3	10	10·6	10	…	…	…	…	…	…
		June.	…	…	9·3	7	8·0	7	…	…	…	…	…	…
		July.	…	…	10·9	12	9·1	12	…	…	…	…	…	…
		August.	…	…	8·9	12	7·6	12	…	…	…	…	…	…
		September.	…	…	10·5	12	8·7	12	…	…	…	…	…	…
		October.	…	…	10·7	8	8·7	8	…	…	…	…	…	…
		November.	…	…	10·1	2	5·4	2	…	…	…	…	…	…
		December.	…	…	11·0	6	7·2	6	…	…	…	…	…	…
Principally clear.	1843.	April.	…	…	…	…	11·0	2	2·3	2	…	…	…	…
		May.	4·5	7	…	…	5·0	7	3·3	7	7·6	7	6·7	7
		June.	3·5	7	…	…	6·0	7	2·9	7	8·3	7	7·9	7
		July.	5·9	10	…	…	5·9	10	7·0	1	7·1	9	7·3	10
		August.	4·7	12	…	…	7·1	12	…	…	6·9	12	7·2	12
		September.	7·4	1	8·8	2	9·7	5	…	…	9·1	5	9·5	5
		October.	…	…	8·0	8	7·1	8	…	…	5·9	8	…	…
		November.	…	…	8·9	7	6·2	6	…	…	4·4	4	…	…
		December.	…	…	7·1	5	6·5	4	…	…	…	…	…	…
	1844.	January.	…	…	8·5	7	7·4	7	…	…	…	…	…	…
		February.	…	…	7·5	6	5·8	6	…	…	…	…	…	…
		March.	…	…	6·6	2	5·6	2	…	…	…	…	…	…
		April.	…	…	10·3	4	9·1	4	…	…	…	…	…	…
		May.	…	…	9·8	5	9·5	5	…	…	…	…	…	…
		June.	…	…	8·8	5	9·0	5	…	…	…	…	…	…
		July.	…	…	8·8	1	10·0	1	…	…	…	…	…	…
		August.	…	…	8·1	6	6·0	6	…	…	…	…	…	…
		September.	…	…	10·8	4	9·9	4	…	…	…	…	…	…
		October.	…	…	9·5	6	8·1	6	…	…	…	…	…	…
		November.	…	…	9·6	7	7·2	7	…	…	…	…	…	…
		December.	…	…	7·2	1	5·7	1	…	…	…	…	…	…
Half-cloudy.	1843.	April.	4·7	1	…	…	6·2	3	3·3	3	4·7	1	4·2	1
		May.	4·1	4	…	…	6·6	4	4·2	4	7·1	4	7·6	4
		June.	3·8	1	…	…	7·3	1	4·0	1	10·8	1	10·6	1
		July.	3·8	7	…	…	6·2	7	4·5	1	5·9	7	6·4	7
		August.	4·5	7	…	…	6·0	7	…	…	5·6	7	6·0	7
		September.	4·7	2	9·4	5	8·1	7	…	…	6·5	7	4·8	7
		October.	…	…	6·3	6	5·6	6	…	…	4·8	6	3·3	1
		November.	…	…	4·5	7	5·6	6	…	…	3·8	1	…	…
		December.	…	…	7·1	1	6·1	1	…	…	…	…	…	…
	1844.	January.	…	…	7·4	5	5·9	5	…	…	…	…	…	…
		February.	…	…	6·2	6	4·6	6	…	…	…	…	…	…
		March.	…	…	6·5	9	4·7	9	…	…	…	…	…	…
		April.	…	…	6·2	3	6·0	3	…	…	…	…	…	…
		May.	…	…	5·5	9	5·4	9	…	…	…	…	…	…
		June.	…	…	7·7	7	7·6	7	…	…	…	…	…	…
		July.	…	…	9·7	5	6·8	4	…	…	…	…	…	…
		August.	…	…	8·4	4	6·4	4	…	…	…	…	…	…
		September.	…	…	10·5	12	8·7	12	…	…	…	…	…	…
		October.	…	…	7·6	6	6·7	6	…	…	…	…	…	…
		November.	…	…	8·0	6	6·4	6	…	…	…	…	…	…
		December.	…	…	…	0	…	0	…	…	…	…	…	…

readings of a similar thermometer placed on different substances, in each state of the sky.

from the effects of radiation, above that of a similar thermometer fully exposed to the sky, placed																	
In air six inches high.		On white raw wool.		On fine flax.		On coarse flax.		On white anwrought cotton wool.		On lead.		On blackened tin.		On white tin.		In focus of metallic parabolic reflector.	
Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.
°		°		°		°		°		°		°		°		°	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10·1	11
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10 5	2
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10·3	7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10·1	2
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·1	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·2	11
...	...	11·7	7	11·0	7	10·0	7	9·4	7	...	...	...	...	...	...	6·6	8
...	...	12·3	5	11·5	6	12·3	5	11·9	4	...	...	...	...	...	...	8·5	6
...	...	...	0	...	0	...	...	...	...	...	...	...	0	...	0	...	0
...	...	13·4	1	10·6	1	...	...	...	...	...	...	9·6	1	8·9	1	8·0	2
...	...	8·8	4	9·1	4	...	...	...	...	...	...	7·6	4	7·7	4	7·0	4
...	...	11·2	7	9·8	7	...	...	...	...	5·9	7	...	...	...	...	6·5	7
...	...	15·3	18	16·2	18	...	...	...	...	9·2	18	...	...	...	...	8·0	18
...	...	11·9	10	13·2	10	...	...	...	...	9·6	4	...	...	...	...	8·1	10
...	...	8·3	4	7·8	4	...	...	...	...	...	...	...	...	...	...	6·8	6
...	...	12·3	9	13·1	9	...	...	...	...	...	...	...	...	...	...	8·2	12
...	...	8·6	12	9·8	12	...	...	...	...	...	...	...	...	...	...	7·1	12
...	...	...	...	12·6	12	...	...	...	...	...	...	...	...	...	...	9·7	12
...	...	...	...	12·4	8	...	...	...	...	...	...	...	...	...	...	6·8	8
...	...	...	...	9·7	2	...	...	...	...	...	...	...	...	...	...	6·0	2
...	...	...	...	12·3	6	...	...	...	...	...	...	...	...	...	...	9·3	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·4	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·8	4
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·6	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·4	10
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·1	12
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9·2	11
3·1	8·0	8·8	2	9·3	2	8·9	2	8·6	2	...	...	...	...	...	...	6·6	8
...	...	9·5	7	9·1	7	9·5	5	8·0	5	...	...	...	...	...	...	7·1	7
...	...	7·6	5	7·0	5	...	...	...	...	...	...	5·9	5	4·9	5	6·1	5
...	...	10·8	7	8·6	7	...	...	...	...	...	...	8·0	7	7·3	7	4·6	7
...	...	7·9	6	7·9	6	...	...	...	...	...	...	7·0	6	6·8	6	5·5	6
...	...	7·5	2	7·8	2	...	...	...	...	5·2	2	...	...	...	...	4·9	2
...	...	13·1	4	14·5	4	...	...	...	...	10·1	4	...	...	...	...	7·4	4
...	...	11·4	4	9·1	4	...	...	...	...	...	...	...	...	...	...	6 0	5
...	...	10·3	4	10·4	5	...	...	...	...	...	...	...	...	...	...	7·7	5
...	...	12·9	1	13·1	1	...	...	...	...	...	...	...	...	...	...	7·1	1
...	...	8·1	6	8·3	6	...	...	...	...	...	...	...	...	...	...	7·5	6
...	...	...	...	12·5	4	...	...	...	...	...	...	...	...	...	...	8·6	5
...	...	...	...	10·4	6	...	...	...	...	...	...	...	...	...	...	8·8	6
...	...	...	...	10·1	7	...	...	...	...	...	...	...	...	...	...	8·1	7
...	...	...	...	7·1	1	...	...	...	...	...	...	...	...	...	...	8·2	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·3	8
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·1	4
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·5	9
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·6	7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·5	7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·2	7
4·2	3·0	5·4	2	4·6	2	4·8	2	4·0	2	5·0	...	...	...	...	...	5·4	6
...	...	6·5	6	8·0	4	8·6	1	4·8	2	...	...	...	...	...	...	4·6	1
...	...	6·9	1	...	...	7·3	1	...	...	...	...	5·9	1	5·9	1	7·9	1
...	...	9·1	5	5·4	5	...	...	...	...	...	...	6·8	5	5·4	5	4·4	5
...	...	4·2	6	5·0	6	...	...	...	...	...	...	5·1	6	4·5	6	3·7	6
...	...	6·7	8	6·9	8	...	...	...	...	5·3	8	...	...	...	...	4·4	9
...	...	8·2	3	8·8	3	...	...	...	...	4·6	3	...	...	...	...	3·4	3
...	...	8·7	4	8·4	4	...	...	...	...	...	...	...	...	...	...	5·9	6
...	...	7·9	2	6·6	4	...	...	...	...	...	...	...	...	...	...	5·0	7
...	...	8·1	3	8·3	3	...	...	...	...	...	...	...	...	...	...	6·3	5
...	...	11·0	4	11·9	4	...	...	...	...	...	...	...	...	...	...	7·5	5
...	...	...	...	12·6	10	...	...	...	...	...	...	...	...	...	...	12 0	2
...	...	...	...	9·3	6	...	...	...	...	...	...	...	...	...	...	6·0	6
...	...	...	...	8·9	6	...	...	...	...	...	...	...	...	...	...	7·6	6
...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...	0

Table (Continued).

General state of the sky during the night previous to reading the instruments.	Year.	Month.	The mean excess in each month, according to the state of the sky with respect to the quantity of clouds, of the readings of a self-registering minimum thermometer placed in air at the height of 4 feet and protected											
			On long grass exposed to ¾ths of the sky.		On long grass.		On short grass.		On garden mould.		In air one inch high.		In air three inches high.	
			Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.
			°		°		°		°		°		°	
Principally cloudy.	1843.	April.	...	...	...	...	...	...	...	...	...	...	...	...
		May.	3·8	6	...	...	3·6	6	3·1	6	5·8	6	5·6	6
		June.	4·5	9	...	...	4·8	9	4·4	9	5·2	9	6·0	9
		July.	3·3	6	...	...	3·1	6	...	...	4·3	5	4·0	6
		August.	5·1	2	...	...	7·0	2	...	...	6·8	2	7·3	2
		September.	5·4	1	6·2	1	5·0	3	...	...	4·0	3	3·6	3
		October.	...	...	6·6	3	4·0	3	...	...	3·4	3	3·3	2
		November.	...	...	3·8	2	4·0	2	...	...	...	...	...	...
		December.	...	...	6·1	7	5·7	7	...	...	...	...	...	...
	1844.	January.	...	...	6·9	7	6·2	7	...	...	...	...	...	...
		February.	...	...	5·6	6	3·4	6	...	...	...	...	...	...
		March.	...	...	6·6	5	5·1	5	...	...	...	...	...	...
		April.	...	...	9·5	2	8·9	2	...	...	...	...	...	...
		May.	...	...	5·2	1	4·7	1	...	...	...	...	...	...
		June.	...	...	8·7	10	7·9	10	...	...	...	...	...	...
		July.	...	...	7·5	9	7·2	9	...	...	...	...	...	...
		August.	...	...	4·9	7	4·4	7	...	...	...	...	...	...
		September.	...	...	6·6	5	5·2	5	...	...	...	...	...	...
		October.	...	...	5·6	1	5·8	1	...	...	...	...	...	...
		November.	...	...	6·0	3	3·8	3	...	...	...	...	...	...
		December.	...	...	...	0	...	0	...	...	...	...	...	...
Cloudy.	1843.	April.	5·7	2	...	...	6·8	2	4·2	2	5·4	2	5·2	2
		May.	3·7	12	...	...	2·8	12	2·1	12	3·7	12	4·8	12
		June.	2·3	5	...	...	1·5	5	1·2	5	2·9	5	3·1	5
		July.	3·0	5	...	...	2·1	5	...	...	2·9	4	2·3	5
		August.	1·5	2	...	...	1·2	2	...	...	1·5	2	1·7	2
		September.	3·0	3	...	...	2·9	3	...	...	3·1	3	3·1	3
		October.	3·7	5	3·7	5	4·2	5	...	...	1·1	5	...	...
		November.	...	...	2·1	8	1·7	7	...	...	1·9	2	...	...
		December.	...	...	3·0	17	2·8	17	...	...	...	...	...	...
	1844.	January.	...	...	3·5	8	2·9	7	...	...	...	...	...	...
		February.	...	...	3·9	7	3·6	7	...	...	...	...	...	...
		March.	...	...	3·2	8	2·8	8	...	...	...	...	...	...
		April.	...	...	2·6	3	2·6	3	...	...	...	...	...	...
		May.	...	...	5·5	9	5·4	9	...	...	...	...	...	...
		June.	...	...	1·7	2	1·6	2	...	...	...	...	...	...
		July.	...	...	3·2	4	2·2	4	...	...	...	...	...	...
		August.	...	...	4·9	7	4·4	7	...	...	...	...	...	...
		September.	...	...	3·1	6	2·9	6	...	...	...	...	...	...
		October.	...	...	5·3	10	4·2	10	...	...	...	...	...	...
		November.	...	...	3·2	12	2·5	12	...	...	...	...	...	...
		December.	...	...	2·7	23	1·1	23	...	...	...	...	...	...

TABLE (Continued).

from the effects of radiation, above that of a similar thermometer fully exposed to the sky, placed																	
In air six inches high.		On white raw wool.		On fine flax.		On coarse flax.		On white unwrought cotton wool.		On lead.		On blackened tin.		On white tin.		In focus of metallic parabolic reflector.	
Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.	Mean excess.	Number of nights.
°		°		°		°		°		°		°		°		°	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·8	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·8	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·5	9
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·6	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7·0	2
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·6	3
...	...	2·5	1	2·5	1	2·5	1	...	...	...	...	...	...	...	...	4·6	3
...	...	4·5	2	4·3	2	...	...	...	...	...	...	...	...	...	...	1·5	2
...	...	6·0	7	...	...	6·1	7	...	...	...	...	5·1	7	4·0	6	5·7	7
...	...	7·0	7	5·6	7	...	...	...	...	...	...	6·7	7	6·3	7	2·6	7
...	...	7·4	6	6·8	6	...	...	...	...	...	...	4·9	6	4·6	6	3·1	6
...	...	8·0	5	7·3	5	...	...	...	...	5·3	1	...	...	...	...	4·2	5
...	...	12·3	2	13·2	2	...	...	...	...	9·0	2	...	...	...	...	7·3	2
...	...	8·7	1	8·7	1	...	...	...	...	...	...	...	...	...	...	6·0	5
...	...	9·1	8	9·0	8	...	...	...	...	...	...	...	...	...	...	−1·3	1
...	...	8·5	7	7·7	7	...	...	...	...	...	...	...	...	...	...	4·8	9
...	...	6·5	5	6·0	6	...	...	...	...	...	...	...	...	...	...	7·9	1
...	...	...	...	7·6	5	...	...	...	...	...	...	...	...	...	...	6·3	5
...	...	...	...	8·8	1	...	...	...	...	...	...	...	...	...	...	6·3	1
...	...	...	...	6·6	3	...	...	...	...	...	...	...	...	...	...	5·7	3
...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·8	4
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·6	12
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·2	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·8	5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·9	2
2·0	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5·1	3
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·4	6
...	...	3·3	7	2·0	5	2·9	4	2·1	4	...	...	2·2	15	2·4	16	2·0	8
...	...	2·4	17	...	...	3·0	17	...	...	...	...	3·5	7	3·7	7	3·3	17
...	...	3·6	8	2·5	8	...	...	...	...	...	...	5·5	6	4·6	6	0·7	8
...	...	4·7	6	5·1	6	...	...	...	...	...	...	...	...	...	...	3·3	7
...	...	3·5	8	3·8	8	...	...	...	...	2·9	8	...	...	...	...	1·8	8
...	...	5·2	3	4·9	3	...	...	...	...	2·6	3	...	...	...	...	2·1	3
...	...	8·7	4	8·4	4	...	...	...	...	...	...	...	...	...	...	4·1	9
...	...	1·8	2	2·5	2	...	...	...	...	...	...	...	...	...	...	3·7	2
...	...	3·3	3	3·6	3	...	...	...	...	...	...	...	...	...	...	3·1	4
...	...	6·5	5	6·0	6	...	...	...	...	...	...	...	...	...	...	4·4	7
...	...	...	...	3·5	6	...	...	...	...	...	...	...	...	...	...	5·4	5
...	...	...	...	7·1	10	...	...	...	...	...	...	...	...	...	...	4·7	10
...	...	...	...	2·5	12	...	...	...	...	...	...	...	...	...	...	2·9	11
...	...	...	...	2·4	23	...	...	...	...	...	...	...	...	...	...	3·4	23

The following Table contains the mean of the values in each year, and for the whole time according to the number of observations.

Table CII.—Showing the excess of reading of the thermometer in Air, above those placed as stated in the 2nd column, in each of the years 1843 and 1844, and for both years together.

General state of the sky during the night previous to reading the instruments.	Situation of the thermometer.	The mean yearly excess, according to the state of the sky, of the reading of a self-registering minimum thermometer placed in air at the height of 4 feet, and protected from radiation, above that of a similar thermometer placed on different substances.								
		1843.			1844.			1843 and 1844.		
		Number of nights.	Sum of excesses.	Mean excess.	Number of nights.	Sum of excesses.	Mean excess.	Whole number of nights.	Whole sum of excesses.	Mean excess.
Cloudy.	On long grass exposed to ¾ths of the sky	29	95·6	3·3	...	.....	...	29	95·6	3·3
	On long grass fully exposed to the sky	30	85·9	2·9	99	360·2	3·7	129	446·1	3·4
	On short grass fully exposed to the sky	58	159·5	2·8	98	281·6	2·9	156	441·1	2·8
	On garden mould	29	40·2	1·4	...	.....	...	29	40·2	1·4
	One inch above grass	34	103·0	3·0	...	.....	...	34	103·0	3·0
	Three inches above grass	31	111·5	3·6	...	.....	...	31	111·5	3·6
	Six inches above grass	...	.....	...	...	.....	...	...	.....	...
	On white raw wool	25	70·6	2·8	40	186·5	4·7	65	257·1	3·9
	On fine flax	6	15·7	2·6	92	363·8	4·0	98	379·5	3·9
	On coarse flax	22	67·6	3·1	...	.....	...	22	67·6	3·1
	On white unwrought cotton wool	5	11·2	2·2	...	.....	...	5	11·2	2·2
	On lead	...	.....	...	11	31·0	2·8	11	31·0	2·8
	On blackened tin	15	33·5	2·2	14	62·7	4·5	29	96·2	3·3
	On white tin	16	38·4	2·4	14	50·7	3·6	40	89·1	2·2
	In focus of metallic reflector	86	281·4	3·3	97	322·9	3·3	183	604·3	3·3
Principally cloudy.	On long grass exposed to ¾ths of the sky	25	101·2	4·1	...	.....	...	25	101·2	4·0
	On long grass fully exposed to the sky	13	76·9	5·9	50	354·7	7·1	63	431·6	6·8
	On short grass fully exposed	39	181·8	4·6	50	303·3	6·1	89	485·1	5·5
	On garden mould fully exposed	16	59·7	3·7	...	.....	...	16	59·7	3·7
	One inch above grass	28	146·0	5·2	...	.....	...	28	146·0	5·2
	Three inches above grass	29	149·0	5·1	...	.....	...	29	149·0	5·2
	Six inches above grass	...	.....	...	...	.....	...	...	.....	...
	On white raw wool	10	53·9	5·4	37	302·0	8·2	47	355·9	7·5
	On fine flax	3	11·1	3·7	46	352·9	7·7	49	364·0	7·4
	On coarse flax	8	45·4	5·7	...	.....	...	8	45·4	5·7
	On white unwrought cotton wool	1	6·5	6·5	...	.....	...	1	6·5	6·5
	On lead	...	.....	...	7	44·3	6·3	7	44·3	6·3
	On blackened tin	7	36·1	5·1	13	75·8	5·8	20	111·9	5·6
	On white tin	6	24·2	4·0	13	71·7	5·3	19	95·9	5·0
	In focus of metallic reflector	49	258·2	5·3	49	237·4	4·9	98	495·6	5·1
Half-cloudy.	On long grass exposed to ¾ths of the sky	22	88·6	4·0	...	.....	...	22	88·6	4·0
	On long grass fully exposed	19	120·7	6·4	58	438·4	7·6	77	559·1	7·3
	On short grass	42	267·3	6·4	57	353·6	6·2	99	620·9	6·3
	On garden mould	10	39·7	4·0	...	.....	...	10	39·7	3·9
	One inch above grass	34	202·5	5·9	...	.....	...	34	202·5	5·9
	Three inches above grass	28	168·9	6·0	...	.....	...	28	168·9	6·0
	Six inches above grass	3	12·5	4·2	...	.....	...	3	12·5	4·2
	On white raw wool	9	56·6	6·3	33	250·7	7·6	42	307·3	7·3
	On fine flax	11	41·2	3·7	49	383·9	7·8	60	425·1	7·1
	On coarse flax	4	25·5	6·4	...	.....	...	4	25·5	6·4
	On white unwrought cotton wool	4	17·6	4·4	...	.....	...	4	17·6	4·4
	On lead	...	.....	...	14	70·7	5·1	14	70·7	5·1
	On blackened tin	1	5·9	5·9	11	64·5	5·9	12	70·4	5·9
	On white tin	1	5·9	5·9	11	53·9	4·9	12	59·8	5·0
	In focus of metallic reflector	62	394·9	6·4	60	336·4	5·6	122	731·3	6·0

TABLE (Continued).

General state of the sky during the night previous to reading the instruments.	Situation of the thermometer.	The mean yearly excess, according to the state of the sky, of the reading of a self-registering minimum thermometer placed in air at the height of 4 feet, and protected from radiation, above that of a similar thermometer placed on different substances.								
		1843.			1844.			1843 and 1844.		
		Number of nights.	Sum of excesses.	Mean excess.	Number of nights.	Sum of excesses.	Mean excess.	Whole number of nights.	Whole sum of excesses.	Mean excess.
			°	°		°	°		°	°
Principally clear.	On long grass exposed to ¾ths of the sky	37	178·5	4·8	...	.....	...	37	178·5	4·8
	On long grass fully exposed to the sky	22	179·2	8·1	55	195·2	9·0	77	374·4	4·9
	On short grass	61	410·7	6·7	55	427·7	7·8	116	838·4	7·2
	On garden mould	17	55·6	3·3	...	.....	...	17	55·6	3·3
	One inch above grass	52	368·3	7·1	...	.....	...	52	368·3	7·1
	Three inches above grass	41	295·1	7·1	...	.....	...	41	295·1	7·2
	Six inches above grass	6	18·7	3·2	...	.....	...	6	18·7	3·1
	On white raw wool	14	122·6	8·8	35	299·7	8·6	49	422·3	3·6
	On fine flax	9	82·6	9·2	54	482·2	8·9	63	564·8	9 0
	On coarse flax	12	100·2	8·3	...	.....	...	12	100·2	8·4
	On white unwrought cotton wool	7	57·2	8·2	...	.....	...	7	57·2	8·2
	On lead	...	.....	...	11	61·1	5·5	11	61·1	5·6
	On blackened tin	5	29·6	5·9	13	97·8	7·5	18	127·4	7·1
	On white tin	5	24·3	4·9	13	91·9	7·1	18	116·2	6·4
	In focus of metallic reflector	78	591·1	7·6	55	374·4	6·8	133	965·5	7·3
Cloudless.	On long grass exposed to ¾ths of the sky	22	143·6	6·5	...	.....	...	22	143·6	6·5
	On long grass fully exposed to the sky	21	203·0	9·7	100	920·2	9·2	121	1123·2	9·3
	On short grass	47	322·1	6·9	98	866·1	8·9	145	1188·2	8·2
	On garden mould	13	73·8	5·7	...	.....	...	13	73·8	5·7
	One inch above grass	38	341·2	5·7	...	.....	...	38	341·2	9·0
	Three inches above grass	29	214·0	7·4	...	.....	...	29	214·0	7·4
	Six inches above grass	1	5·2	5·2	...	.....	...	1	5·2	5·2
	On white raw wool	13	153·5	11·8	60	726·2	12·1	73	879·7	12·1
	On fine flax	17	146·6	8·6	91	1123·6	12·3	108	1270·2	11·8
	On coarse flax	12	131·7	11·0	...	.....	...	12	131·7	10·9
	On white unwrought cotton wool	11	113·1	10·3	...	.....	...	11	113·1	10·3
	On lead	...	.....	...	29	245·8	8·5	29	245·8	8·5
	On blackened tin	...	.....	...	5	40·1	8·0	5	40·1	8·0
	On white tin	...	.....	...	5	39·8	8·0	5	39·8	7·9
	In focus of metallic reflector	81	768·1	9·5	99	770·1	7·8	180	1538·2	8·5

An examination of this Table shows, that on cloudy nights the results derived from every substance, with the single exception of garden mould, are nearly the same; and on partially cloudy nights they are different; the greatest differences occurring on cloudless nights. The reading of the thermometer on garden mould was always the nearest to the reading of the thermometer in the air; those on raw wool and on flax departed the most from it; and those placed, at the distance of one inch to two inches above the top of grass, on a sheet of lead or tin, were all higher than that on garden mould and less than that on wool; and they were all nearly identical with that of the thermometer in the reflector, notwithstanding much heat during the course of a whole night must have passed from the earth to the surface of the lead and tin, which were placed on it.

In this respect the results are somewhat different from those obtained from simultaneous observations of mercurial thermometers; but it would certainly seem that a thermometer placed on a sheet of metal on the ground will read as low as that in the reflector, although that of the latter would attain its lowest reading in less time than that of the former.

From the numbers in this table the numbers in the first ten columns of Table CVI. are formed.

As in a previous part of this paper it has been stated that on cloudy nights a thermometer read differently according as the cloud was high or low, the following Table has been formed by collecting all those cases in which the night has been cloudy throughout.

TABLE CIII.—Showing the results on totally cloudy nights, but the clouds *not* cirrostratus.

The sky covered with cloud during the night, the cloud other than cirrostratus.												
Year.	Month, day and hour of reading the instruments.		The excess of the reading of a self-registering minimum therm. placed in air at the height of 4 feet and protected from radiation, above that of a similar thermometer fully exposed to the sky, placed									
			On long grass.	On short grass.	On white raw wool.	On fine flax.	On coarse flax.	On white unwrought cotton wool.	On blackened tin.	On white tin.	In focus of metallic parabolic reflector.	
		d h	°	°	°	°	°	°	°	°	°	°
1842.	Nov.	7 21	.....	.....	.....	.....	.....	.....	.....	.....	9·3	.....
		9 21	.....	.....	.....	.....	.....	.....	.....	.....	9·0	.....
		17 21	.....	.....	.....	.....	.....	.....	.....	.....	9·4	.....
		20 21	.....	.....	.....	.....	.....	.....	.....	.....	8·7	.....
1843.	Feb.	14 21	.....	.....	.....	.....	.....	.....	.....	.....	13·3	.....
		25 21	.....	.....	.....	.....	.....	.....	.....	.....	8·5	.....
	Nov.	10 21	9·7	7·6	12·6	12·3	13·4	12·2	.....	.....	9·5	32·6
1844.	Feb.	14 21	8·5	7·6	14·8	13·8	.....	.....	7·3	6·8	7·5	36·8
	May	9 21	10·7	9·9	9·3	9·4	.....	.....	.....	.....	11·4	51·7
	Oct.	10 21	10·0	6·4	.....	11·5	.....	.....	.....	.....	7·9	44·5

Table CIV. has been formed by collecting all those cases in which the night has been cloudy throughout, and the clouds have been noted as being high; and Table CV. has been formed in a similar way from all those marked low. Those cloudy nights during which the height of the cloud was not noted have not been used. The means of the results in Tables CIII., CIV. and CV. are contained in Table CVI.

TABLE CIV.—Showing the results, at times with a totally cloudy sky, the clouds being cirrostratus from 3000 to 4000 feet high.

The sky covered with a high cirrostratus cloud during the night previous to reading the instruments.																		
Year.	Month, day and hour of reading the instruments.		The excess of the reading of a self-registering minimum thermometer, placed in air at the height of 4 feet and protected from radiation, above that of a similar thermometer fully exposed to the sky, placed															Minimum reading of a therm. at the height of 4 feet protected from radiation.
			On long grass exposed to 7ths of the sky.	On long grass.	On short grass.	On garden mould.	In air one inch high.	In air three inches high.	In air six inches high.	On white raw wool.	On fine flax.	On coarse flax.	On white unwrought cotton wool.	On lead.	On blackened tin.	On white tin.	In focus of metallic parabolic reflector.	
		d h	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1843.	April	28. 21	4·0	.....	5·6	2·3	4·8	3·0	.....	.....	.....	.....	.....	.....	.....	.....	6·6	41·8
		29. 21	7·3	.....	8·1	6·2	6·0	7·3	.....	.....	.....	.....	.....	.....	.....	.....	7·3	46·0
	May	12. 21	7·5	.....	5·5	6·0	3·3	7·6	.....	.....	.....	.....	.....	.....	.....	.....	2·1	51·3
		13. 21	3·0	.....	4·5	−0·5	4·5	3·5	.....	.....	.....	.....	.....	.....	.....	.....	3·8	45·0
		15. 21	5·4	.....	2·1	2·4	3·4	3·2	.....	.....	.....	.....	.....	.....	.....	.....	3·7	49·4
		16. 21	9·3	.....	6·3	.....	7·3	10·3	.....	.....	.....	.....	.....	.....	.....	.....	5·0	49·3
		23. 21	4·6	.....	6·1	5·8	8·9	9·0	.....	.....	.....	.....	.....	.....	.....	.....	2·8	52·6
	June	14. 21	4·5	.....	5·9	3·6	6·8	7·1	.....	.....	.....	.....	.....	.....	.....	.....	6·4	57·0
	July	18. 21	3·8	.....	9·8	.....	9·6	5·1	.....	.....	.....	.....	.....	.....	.....	.....	7·3	52·3
		20. 21	4·0	.....	4·0	.....	4·0	4·1	.....	.....	.....	.....	.....	.....	.....	.....	5·1	54·1
	September	3. 21	5·7	.....	3·7	.....	4·2	4·6	.....	.....	.....	.....	.....	.....	.....	.....	7·2	57·2
		8. 21	4·8	.....	5·4	.....	5·3	5·6	.....	.....	.....	.....	.....	.....	.....	.....	8·6	61·6
	October	11. 21	.....	7·3	5·0	.....	3·8	.....	2·3	.....	.....	.....	.....	.....	.....	.....	6·4	42·3
	November	5. 21	.....	6·3	4·0	.....	3·5	.....	.....	7·7	6·5	8·5	4·7	.....	.....	.....	3·7	40·7
	Decemb.	13. 21	.....	6·8	7·8	.....	.....	.....	.....	8·3	.....	7·1	.....	.....	6·5	5·3	2·3	39·3
		16. 21	.....	7·5	5·9	.....	.....	.....	.....	5·6	.....	5·9	.....	.....	.....	3·2	5·7	44·7
		20. 21	.....	3·9	2·4	.....	.....	.....	.....	1·9	.....	2·2	.....	.....	1·9	1·9	3·2	41·4
		23. 21	.....	5·6	4·8	.....	.....	.....	.....	4·2	.....	5·0	.....	.....	4·0	3·8	4·5	49·8
		29. 21	.....	3·2	3·2	.....	.....	.....	.....	3·3	.....	3·5	.....	.....	2·5	2·6	5·2	38·5
		30. 21	.....	2·1	2·5	.....	.....	.....	.....	2·1	.....	2·8	.....	.....	2·1	2·5	3·7	39·3
1844.	January	8. 21																
		17. 21	.....	4·5	4·2	.....	.....	.....	.....	3·9	3·3	.....	.....	.....	4·5	1·7	0·5	36·5
		23. 21	.....	4·6	4·2	.....	.....	.....	.....	5·9	4·6	.....	.....	.....	4·9	3·9	2·4	36·2
	February	11. 21	.....	6·0	4·1	.....	.....	.....	.....	7·2	4·1	.....	.....	.....	5·2	4·7	4·7	30·2
	March	4. 21	.....	5·9	4·2	.....	.....	.....	.....	5·6	5·2	.....	.....	5·3	.....	.....	5·9	32·4
		8. 21	.....	4·6	3·0	.....	.....	.....	.....	3·8	3·1	.....	.....	3·0	.....	.....	3·5	36·2
		16. 21	.....	8·1	7·7	.....	.....	.....	.....	9·1	9·1	.....	.....	6·3	.....	.....	4·1	46·1
	April	13. 21	.....	4·9	5·1	.....	.....	.....	.....	7·7	8·4	.....	.....	5·3	.....	.....	3·1	48·7
	August	24. 21	.....	7·6	5·8	.....	.....	.....	.....	8·5	7·3	.....	.....	.....	.....	.....	6·5	52·3
		25. 21	.....	4·4	3·2	.....	.....	.....	.....	.....	5·3	.....	.....	.....	.....	.....	9·1	52·4
	Septemb.	14. 21	.....	4·8	4·4	.....	.....	.....	.....	.....	4·9	.....	.....	.....	.....	.....	6·0	57·3
		15. 21	.....	4·1	4·6	.....	.....	.....	.....	.....	4·8	.....	.....	.....	.....	.....	5·9	61·4
	October	1. 21	.....	5·1	4·6	.....	.....	.....	.....	.....	5·6	.....	.....	.....	.....	.....	3·2	57·6
		12. 21	.....	5·7	6·0	.....	.....	.....	.....	.....	9·8	.....	.....	.....	.....	.....	3·6	55·8
		20. 21	.....	10·0	6·4	.....	.....	.....	.....	.....	11·5	.....	.....	.....	.....	.....	7·9	44·5
		23. 21	.....	7·7	9·7	.....	.....	.....	.....	.....	13·3	.....	.....	.....	.....	.....	5·0	35·5
		25. 21	.....	9·1	5·5	.....	.....	.....	.....	.....	16·1	.....	.....	.....	.....	.....	7·9	43·1
	November	5. 21	.....	5·1	2·6	.....	.....	.....	.....	.....	4·1	.....	.....	.....	.....	.....	2·2	39·1
		14. 21	.....	5·2	5·2	.....	.....	.....	.....	.....	1·8	.....	.....	.....	.....	.....	2·8	47·6
	Decemb.	15. 21	.....	5·1	3·6	.....	.....	.....	.....	.....	4·6	.....	.....	.....	.....	.....	4·8	35·4
		22. 21	.....	4·9	2·9	.....	.....	.....	.....	.....	4·1	.....	.....	.....	.....	.....	5·9	29·1
		30. 21	.....	5·8	3·4	.....	.....	.....	.....	.....	2·5	.....	.....	.....	.....	.....	5·9	34·1
		31. 21	.....	4·9	2·7	.....	.....	.....	.....	.....	2·9	.....	.....	.....	.....	.....	3·9	35·1

TABLE CV.—Showing the results with a totally cloudy sky, the clouds being cirrostratus and less than 2000 feet high.

The sky covered with a low cirrostratus cloud during the night previous to reading the instruments.

Year.	Month, day and hour of reading the instruments.	The excess of the reading of a self-registering minimum thermometer, placed in air at the height of 4 feet and protected from radiation, above that of a similar thermometer fully exposed to the sky, placed															Minimum reading of a thermometer at 4 feet high protected from radiation.
		On long grass exposed to $\frac{3}{4}$ths of the sky.	On long grass.	On short grass.	On garden mould.	In air one inch high.	In air three inches high.	In air six inches high.	On white raw wool.	On fine flax.	On coarse flax.	On white unwrought cotton wool.	On lead.	On blackened tin.	On white tin.	In focus of metallic parabolic reflector.	
	d h	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1843.	May 5 21	2·4	.....	0·9	1·4	2·7	2·7	.....	.....	.....	.....	.....	.....	.....	.....	2·0	50·2
	17 21	2·0	.....	0·0	1·8	4·0	4·0	.....	.....	.....	.....	.....	.....	.....	.....	4·5	44·0
	18 21	1·7	.....	−0·9	0·7	1·5	2·9	.....	.....	.....	.....	.....	.....	.....	.....	3·8	44·8
	30 21	3·3	.....	1·9	2·2	3·0	3·1	.....	.....	.....	.....	.....	.....	.....	.....	2·8	50·3
	June 7 21	2·1	.....	1·1	1·2	3·9	1·8	.....	.....	.....	.....	.....	.....	.....	.....	1·4	49·9
	12 21	...	.....	.....	.....	0·8	.....	.....	.....	.....	.....	.....	.....	.....	.....	2·2	48·8
	17 21	0·6	.....	1·6	−1·9	3·0	2·1	.....	.....	.....	.....	.....	.....	.....	.....	2·0	50·6
	July 12 21	1·3	.....	1·1	.....	1·1	0·9	.....	.....	.....	.....	.....	.....	.....	.....	1·8	55·3
	28 21	0·2	.....	0·2	.....	−0·1	−0·2	.....	.....	.....	.....	.....	.....	.....	.....	1·1	53·1
	Aug. 23 21	0·7	.....	1·3	.....	1·4	1·2	.....	.....	.....	.....	.....	.....	.....	.....	3·9	53·9
	29 21	2·3	.....	1·2	.....	1·7	2·2	.....	.....	.....	.....	.....	.....	.....	.....	3·8	61·0
	Oct. 8 21	.....	0·7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·9	48·5
	10 21	.....	3·3	0·9	.....	0·9	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·7	46·9
	20 21	.....	6·9	0 6	.....	−0·5	.....	1·7	6·3	5·8	5·9	2·8	.....	.....	.....	3·8	38·3
	30 21	.....	0·3	1·8	.....	1·6	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·6	51·1
	31 21	.....	.....	0·2	.....	0·0	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·0	42·5
	Nov. 2 21	.....	−1·3	−0·3	.....	0·3	.....	.....	0·6	0·2	−0·1	−0·1	.....	.....	.....	−0·1	41·2
	15 21	.....	1·6	0·3	.....	.....	.....	.....	3·4	−0·4	0·2	1·3	.....	.....	.....	1·8	31·6
	17 21	.....	2·5	2·7	.....	.....	.....	.....	3·5	3·7	3·1	2·5	.....	.....	.....	2·7	37·7
	21 21	.....	4·1	4·3	.....	.....	.....	.....	4·6	.....	.....	.....	.....	.....	.....	3·6	52·6
	22 21	.....	2·4	2·1	.....	.....	.....	.....	3·5	.....	.....	.....	.....	.....	.....	2·8	44·6
	25 21	.....	−0·3	−4·1	.....	.....	.....	.....	−0·1	−0·1	.....	.....	.....	.....	.....	0·1	45·9
	30 21	.....	1·6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·2	45·7
	Dec. 3 21	.....	2·3	2·3	.....	.....	.....	.....	2·1	.....	2·0	.....	.....	.....	.....	3·3	45·3
	4 21	.....	1·9	2·2	.....	.....	.....	.....	1·7	.....	1·5	.....	.....	2·1	2·2	2·8	45·5
	9 21	.....	2·5	−1·9	.....	.....	.....	.....	0·6	.....	1·1	.....	.....	0 8	1·1	2·6	35·1
	11 21	.....	1·1	1·4	.....	.....	.....	.....	0·3	.....	2·2	.....	.....	0·4	0·2	2·9	30·4
	12 21	.....	3·8	3·4	.....	.....	.....	.....	2·8	.....	5·3	.....	.....	1·6	4·3	2·8	25·6
	18 21	.....	2·5	3·2	.....	.....	.....	.....	2·4	.....	3·1	.....	.....	2·5	2·7	3·7	42·5
	19 21	.....	0·6	0·0	.....	.....	.....	.....	1·1	.....	2·0	.....	.....	1·3	2·3	2·6	42·3
	21 21	.....	2·9	2·7	.....	.....	.....	.....	2·2	.....	2·3	.....	.....	1·8	2·1	3·9	41·9
	22 21	.....	0·5	1·2	.....	.....	.....	.....	−0·3	.....	0·9	.....	.....	0·3	0·9	2·3	42·5
	26 21	.....	1·5	2·5	.....	.....	.....	.....	0·9	.....	1·5	.....	.....	1·5	1·9	2·7	42·5
	28 21	.....	1·8	2·0	.....	.....	.....	.....	1·9	.....	1·6	.....	.....	1·2	1·4	2·3	42·5

Table (Continued).

The sky covered with a low cirrostratus cloud during the night previous to reading the instruments.																		
Year.	Month, day and hour of reading the instruments.		The excess of the reading of a self-registering minimum thermometer, placed in air at the height of 4 feet and protected from the effects of radiation, above that of a similar thermometer fully exposed to the sky, placed															Minimum reading of a thermometer at 4 feet high protected from radiation.
			On long grass exposed to $\frac{1}{4}$ths of the sky.	On long grass.	On short grass.	On garden mould.	In air one inch high.	In air three inches high.	In air six inches high.	On white raw wool.	On fine flax.	On coarse flax.	On white unwrought cotton wool.	On lead.	On blackened tin.	On white tin.	In focus of metallic parabolic reflector.	
	d	h	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1844. Jan.	9	21	.....	1·7	0·9	.....	.....	.....	.....	1·7	0·2	.....	.....	.....	0·9	0·5	0·2	30·7
	12	21	.....	1·8	1·7	.....	.....	.....	.....	2·4	1·2	.....	.....	.....	2·4	1·9	−0·8	39·2
	13	21	.....	1·6	0·9	.....	.....	.....	.....	1·5	0·7	.....	.....	.....	1·7	1·2	−1·8	32·7
Feb.	21	21	.....	0·3	0·5	.....	.....	.....	.....	1·4	−0·2	.....	.....	0·4	.....	.....	−1·5	32·0
Mar.	14	21	.....	0·5	1·1	.....	.....	.....	.....	0·7	2·8	.....	.....	1·7	.....	.....	−0·2	38·1
	22	21	.....	1·3	1·1	.....	.....	.....	.....	1·5	2·5	.....	.....	1·1	.....	.....	−1·2	39·8
	31	21	.....	0·6	0·2	.....	.....	.....	.....	2·0	0·2	.....	.....	−0·2	.....	.....	0·7	37·3
April	26	21	.....	0·6	0·1	.....	.....	.....	.....	2·0	1·3	.....	.....	0·4	.....	.....	1·1	46·1
May	22	21	.....	0·2	0·0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·4	47·4
Sept.	9	21	.....	0·8	1·1	.....	.....	.....	.....	.....	0·8	.....	.....	.....	.....	.....	5·8	55·8
Oct.	15	21	.....	2·0	1·7	.....	.....	.....	.....	.....	2·2	.....	.....	.....	.....	.....	2·9	46·7
	24	21	.....	1·1	0·5	.....	.....	.....	.....	.....	1·9	.....	.....	.....	.....	.....	2·7	47·2
	29	21	.....	3·7	2·4	.....	.....	.....	.....	.....	2·7	.....	.....	.....	.....	.....	7·7	42·7
Nov.	12	21	.....	0·8	0·9	.....	.....	.....	.....	.....	−0·1	.....	.....	.....	.....	.....	1·8	48·8
	17	21	.....	0·8	0·6	.....	.....	.....	.....	.....	0·6	.....	.....	.....	.....	.....	2·7	48·7
Dec.	1	21	.....	1·9	0·8	.....	.....	.....	.....	.....	2·1	.....	.....	.....	.....	.....	3·9	34·1
	2	21	.....	3·0	0·4	.....	.....	.....	.....	.....	2·3	.....	.....	.....	.....	.....	5·1	32·3
	3	21	.....	2·2	1·1	.....	.....	.....	.....	.....	1·6	.....	.....	.....	.....	.....	3·6	34·1
	8	21	.....	2·3	2·8	.....	.....	.....	.....	.....	−0·4	.....	.....	.....	.....	.....	3·9	25·1
	9	21	.....	1·7	0·3	.....	.....	.....	.....	.....	8·5	.....	.....	.....	.....	.....	3·3	27·8
	10	21	.....	1·2	−0·2	.....	.....	.....	.....	.....	2·7	.....	.....	.....	.....	.....	3·0	27·7
	12	21	.....	0·7	−0·8	.....	.....	.....	.....	.....	0·4	.....	.....	.....	.....	.....	2·9	23·2
	13	21	.....	0·3	−0·9	.....	.....	.....	.....	.....	2·9	.....	.....	.....	.....	.....	2·2	24·4
	14	21	.....	2·8	1·4	.....	.....	.....	.....	.....	2·3	.....	.....	.....	.....	.....	2·7	28·1
	16	21	.....	1·1	0·4	.....	.....	.....	.....	.....	0·3	.....	.....	.....	.....	.....	2·9	37·1
	17	21	.....	2·0	1·1	.....	.....	.....	.....	.....	1·1	.....	.....	.....	.....	.....	3·1	38·1
	18	21	.....	0·8	0·3	.....	.....	.....	.....	.....	0·3	.....	.....	.....	.....	.....	2·3	40·3
	23	21	.....	2·4	0·7	.....	.....	.....	.....	.....	1·5	.....	.....	.....	.....	.....	4·0	29·5
	24	21	.....	2·3	1·8	.....	.....	.....	.....	.....	2·3	.....	.....	.....	.....	.....	2·3	31·3
	25	21	.....	1·8	0·8	.....	.....	.....	.....	.....	1·3	.....	.....	.....	.....	.....	3·4	31·1
	27	21	.....	3·6	0·9	.....	.....	.....	.....	.....	3·8	.....	.....	.....	.....	.....	2·6	29·8
	28	21	.....	1·7	1·0	.....	.....	.....	.....	.....	1·3	.....	.....	.....	.....	.....	3·2	40·5
	29	21	.....	0·5	−1·1	.....	.....	.....	.....	.....	−0·5	.....	.....	.....	.....	.....	2·2	37·5

BLE CVI.—The sum of the excesses, and the mean excess of a self-registering minimum thermometer placed in Air at the height of four feet above the soil and protected from the effects of radiation, above those of similar thermometers placed on different substances, or in different situations, fully exposed to the sky.

situation of the thermometer.	The sum of the excess of the readings of the thermometer in air above the readings of other thermometers placed as stated.										The mean excess.				Sum and mean excess, at times when							
	General state of the sky.										Mean state of the sky.				The sky was covered with cirrostratus cloud during the night whose						Sky was covered with cloud all night, but not of the cirro-stratus character.	
	Cloudy.		Principally cloudy.		Half-cloudy.		Principally clear.		Cloudless.						Height was from 3000 to 4000 feet.			Whose height was from 1000 to 2000 feet.			Difference corresponding to a difference of height of about 2000 feet.		
	Number of nights.	Sum of excesses.	Number of nights.	Sum of excesses.	Number of nights.	Sum of excesses.	Number of nights.	Sum of excesses.	Number of nights.	Sum of excesses.	Whole number of nights.	Whole sum of excesses.	Mean excess.	Relative excess, that of long grass being =1000.	Number of nights.	Sum of excesses.	Mean excess.	Number of nights.	Sum of excesses.	Mean excess.		Number of nights.	Mean excess.
		°		°		°		°		°		°	°			°	°		°	°			°
long grass exposed ⅔ths of the sky...	29	95·6	25	101·2	22	88·6	37	178·5	22	143·6	135	607·5	4·50	715	12	63·9	5·3	10	16·6	1·7	3·6		
long grass fully exposed	129	446·1	63	431·6	77	559·1	77	374·4	121	1123·2	467	2934·4	6·29	1000	30	170·8	5·7	55	92·7	1·6	4·1	4	9·7
short grass	156	441·1	89	485·1	99	620·9	116	838·4	145	1188·2	605	3573·7	5·91	939	42	205·7	4·9	64	64·5	1·0	3·9	4	7·9
garden mould	29	40·2	16	59·7	10	39·7	17	55·6	13	73·8	85	269·0	3·17	500	7	25·8	3·7	6	5·4	0·9	2·8		
⅛ inch above grass ...	34	103·0	28	146·0	34	202·5	52	368·3	38	341·2	186	1161·0	6·24	992	14	75·4	5·5	16	25·3	1·6	3·9		
three inches above grass	31	111·5	29	149·0	28	168·9	41	295·1	29	214·0	158	938·5	5·94	944	12	70·4	5·9	10	20·7	2·1	3·8		
inches above grass...	...	.....	...	.....	3	12·5	6	18·7	1	5·2	10	36·4	3·64	579	1	2·3	2·3	1	1·7	1·7	0·6		
white raw wool	65	257·1	47	355·9	42	307·3	49	422·3	73	879·7	276	2222·3	8·05	1280	15	84·8	5·7	26	51·3	2·0	3·7	3	12·2
fine flax	98	379·5	49	364·0	60	425·1	63	564·8	108	1270·2	378	3003·6	7·95	1264	23	152·9	7·1	37	59·8	1·6	5·5	4	11·8
coarse flax	22	67·6	8	45·4	4	25·5	12	100·2	12	131·7	58	370·4	6·39	1016	7	35·0	5·0	15	32·6	2·2	2·8	1	13·4
white unwrought cotton wool	5	11·2	1	6·5	4	17·6	7	57·2	11	113·1	28	205·6	7·34	1167	1	4·7	4·7	4	6·5	1·6	3·1	1	12·2
lead	11	31·0	7	44·3	14	70·7	11	61·1	29	245·8	72	452·9	6·29	1000	4	19·9	5·0	5	3·4	0·7	4·3		
blackened tin	29	96·2	20	111·9	12	70·4	18	127·4	5	40·1	84	446·0	5·31	844	8	31·6	4·0	13	18·5	1·4	2·6	1	7·3
white tin	40	89·1	19	95·9	12	59·8	18	116·2	5	39·8	94	400·8	4·26	677	9	29·6	3·3	13	22·7	1·7	1·6	1	6·8
focus of reflector	183	604·3	98	495·6	122	731·3	133	965·5	180	1538·2	716	4334·9	6·05	962	42	205·4	4·9	67	158·3	2·4	2·5	10	9·4

The numbers in the column of mean excess exhibit the mean difference between the reading of a self-registering minimum thermometer placed in air, at the height of four feet, and protected as much as possible from the effects of radiation, and the readings of similar thermometers placed as stated in the first column. The first results are those relating to grass; that deduced from grass exposed to three-fourths of the sky, is about three-fourths of that deduced from grass exposed to the whole of the sky; and that from long grass is larger than that from short grass. Of all the substances upon which experiments have been made with spirit thermometers, those on which the lowest readings have occurred were the filamentous, viz. wool and flax, and they were nearly alike.

The next class of bodies consisted of metals; of these lead exhibited the lowest readings in the mean; but this must have arisen from the circumstance of its having been generally used on the clearest nights only, during which there was found to be a very small difference between its readings and that of the thermometer in the reflector; in fact in all simultaneous observations it was found that the readings of the latter thermometer had no advantage over the readings of one placed on lead.

The thermometers which were placed within a few inches of the top of grass exhibited higher readings than those of the last class, and those which were from one to three inches from the top of grass, generally read the same as that in the reflector.

The reading which most nearly agreed with that in air was on garden mould, which was about a mean between that on long grass and that in the air; these observations were made on ground undisturbed; the readings would have been still nearer those in the air, had the ground been frequently disturbed so as to have been loose, as it was found in this state to admit the heat to pass more readily from beneath to the surface.

The numbers in the next column represent the relative radiating power of the several substances deduced by considering the mean result from long grass to be represented by 1000.

The following columns of the table represent the mean results for each substance on nights wholly cloudy, but the clouds of different heights. This result is very important, as it shows that the amount of radiation may be large on a wholly cloudy night, providing that the clouds be high. The differences between the results on a cloudy night when the clouds are high and when they are low, are very great; the numbers in the Table exhibit the mean difference between the results deduced when the clouds have been high, and when moderately low.

The last column shows that on a cloudy night, providing the kind of cloud be other than cirrostratus, the amount of radiation may nearly equal that on a cloudless night.

At a very early stage in the investigation it was found that the variation in the height of the clouds had a very considerable effect on the reading of a thermometer placed on any substance fully exposed to the sky, during those nights that the sky was wholly covered with an apparent uniform cirrostratus cloud.

At the Royal Observatory at Greenwich, the reflexion of the lights of London on the clouds is well seen; at times this appears as a narrow well-defined band of light, at the elevation of several degrees, and at other times as a broad diffused band; the lower limit of which is sometimes below the horizon. It was soon found that the difference between the reading of the thermometer in air and that on grass was greater, the greater the height of this band of light. On very many nights, and several times in the course of the same night, the height of the upper and lower edges of this band of reflected light was measured above the horizon, and from these observations that of the centre was determined; at the same times the readings of the thermometers in air and on grass were taken. By these means it was found that when the centre of the reflected light was above the horizon of Greenwich by—

4°, the excess of reading of the thermometer in air above that on grass was 1°·6
6°, the excess of reading of the thermometer in air above that on grass was 2°·5
8°, the excess of reading of the thermometer in air above that on grass was 3°·9

And whenever the centre of the band was in height less than 4°, the lower limit was generally below the horizon, and the height of the centre could not be determined; but at these times the differences between the readings of the two thermometers was seldom so much as a degree, and it was generally less, and frequently there was no difference.

The Cathedral of St. Paul is very nearly the centre of London, and it may be considered to be immediately under the centre of the reflected light; its distance from the Magnetic House is more than 25,700 feet; at this distance one degree subtends about 450 feet; the height of the ground where the observations were taken is about 100 feet higher than the ground at London.

From the above data, it appears that when the reflexion of the London lights was 4°, 6°, and 8° high, the distances of the clouds from the earth was 1900, 2800, and 3700 feet respectively.

A similar investigation was made by measuring the distance of the band from the cross on the cathedral, whose height above the ground is about 400 feet, and results were obtained differing from the preceding by about fifty feet; a much smaller number of observations, however, were used in deducing the latter results than were used in deducing the former.

As a difference of 0°·7 took place in the reading of a thermometer on grass for every variation of a degree in the height of the reflected lights, it follows that a difference of 1° in the readings of the thermometer on the grass indicated a difference of 630 feet in the height of the cloud.

TABLE CVII.—Showing the monthly mean temperature, and state of cloudiness of the nights, also the greatest differences and the lowest thermometrical readings each month.

Year.	Month.	Mean temperature of the month by a thermometer in air at 4 feet high, protected from radiation.	Mean reading of all the minimum readings, in the month, of the thermometer in air.	Excess of the mean reading of the minimum thermometer in air at 4 feet high, above that of a similar thermometer placed in the focus of a reflector.	Mean state of the sky with respect to the quantity of cloud during the night, 10 being quite cloudy, and 0 being quite clear.	Mean yearly excess of the reading of thermometer in air, above that in reflector.	The greatest excess, in each month, of the minimum reading of a self-registering thermometer, placed in air 4 feet above the ground and protected from radiation, above the minimum reading of a similar thermometer fully exposed to the sky, placed							The lowest reading in each month of the self-registering thermometer placed						
							In focus of metallic parabolic reflector.	On long grass	On short grass.	On white raw wool.	On flax.	On lead.	On tin.	In air at 4 feet high.	In focus of metallic parabolic reflector.	On long grass.	On short grass.	On white raw wool.	On flax.	On lead.	On tin
		°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1841.	February	35·3	31·6	0·7	9·0	...	5·8	...	...	...	...	...	...	18·8	14·0						
	March	46·2	38·7	5·3	4·7	...	13·4	...	...	...	...	...	...	29·5	26·3						
	April	47·0	39·9	5·0	6·3	...	11·8	...	...	...	...	...	...	31·8	24·4						
	May	56·8	48·4	3·8	4·9	...	8·5	...	...	...	...	...	...	41·2	33·4						
	June	56·4	48·2	4·5	5·5	...	11·2	...	...	...	...	...	...	40·3	32·0						
	July	57·8	51·5	3·5	6·8	4·0	10·9	...	...	...	...	...	...	44·3	39·0						
	August	60·5	54·3	2·9	6·5	...	14·0	...	...	...	...	...	...	45·5	39·0						
	September	58·1	51·2	4·2	5·2	...	11·7	...	...	...	...	...	...	36·6	31·0						
	October	48·8	43·9	3·6	6·8	...	12·9	...	...	...	...	...	...	32·2	29·0						
	November	42·7	38·0	5·0	7·2	...	10·0	...	...	...	...	...	...	22·6	12·6						
	December	40·5	35·4	5·6	6·8	...	11·8	...	...	...	...	...	...	24·3	12·5						
1842.	January	32·9	29·3	5·3	7·8	...	12·0	...	...	...	...	...	...	23·2	12·5						
	February	40·8	36·0	4·9	7·5	...	9·3	...	...	...	...	...	...	26·4	21·4						
	March	44·9	39·2	4·5	6·9	...	8·2	...	...	...	...	...	...	29·9	23·2						
	April	45·2	37·3	5·1	4·6	...	9·3	...	...	...	...	...	...	28·0	20·5						
	May	53·2	45·0	5·0	5·2	...	9·5	...	...	...	...	...	...	36·4	30·5						
	June	62·9	52·2	7·1	4·6	...	16·0	...	...	...	...	...	...	44·7	35·0						
	July	60·2	52·1	5·8	6·3	5·3	10·4	...	...	...	...	...	...	45·5	37·5						
	August	65·4	56·3	5·1	6·5	...	8·3	...	...	...	...	...	...	47·5	41·7						
	September	56·4	49·8	3·3	6·0	...	8·0	...	...	...	...	...	...	41·1	36·5						
	October	45·4	39·3	6·2	5·8	...	14·2	...	...	...	...	...	...	28·3	17·2						
	November	42·8	39·0	6·8	7·4	...	11·9	...	...	...	...	...	...	31·1	20·6						
	December	45·0	40·2	4·6	7·3	...	9·4	...	...	...	...	...	...	30·8	24·7						
1843.	January	39·9	35·4	7·1	7·0	...	11·7	...	...	...	...	...	...	24·0	12·3						
	February	36·0	31·9	6·5	7·9	...	14·1	...	...	...	...	...	...	20·3	7·0						
	March	42·9	37·5	8·2	5·8	...	17·6	...	...	...	...	...	...	29·0	11·4						
	April	47·1	40·7	6·9	5·9	...	13·0	...	11·2	...	...	...	...	27·2	17·8						
	May	52·2	45·5	5·1	6·9	...	10·5	...	11·9	...	...	...	...	35·4	28·0	...	28·0				
	June	56·3	49·0	6·8	6·9	...	13·0	...	11·7	...	...	...	...	42·9	33·2	...	31·8				
	July	60·9	53·5	6·2	7·1	6·5	11·3	...	13·6	...	...	...	...	44·6	35·2	...	36·0				
	August	62·1	55·2	7·6	5·4	...	11·8	...	13·7	...	...	...	...	47·2	37·8	...	35·0				
	September	59·5	52·3	7·9	4·5	...	13·0	13·8	13·3	...	...	...	...	36·0	27·6	25·8	27·9				
	October	48·0	42·0	5·5	6·0	...	11·0	11·2	9·0	14·0	17·3	...	...	28·5	17·5	18·5	19·5	14·5	11·2		
	November	43·8	38·7	5·7	5·8	...	10·1	11·5	8·4	16·1	15·4	...	...	27·4	19·2	15·9	19·0	13·5	13·2		
	December	43·9	40·3	4·5	8·8	...	7·2	10·2	9·5	10·0	10·2	...	9·2	25·6	22·8	21·8	22·2	22·8	20·3	...	21·0
1844.	January	39·1	34·6	3·2	6·0	...	8·3	10·2	9·9	13·7	10·6	...	9·6	18·6	9·8	...	...	...	9·2		
	February	35·2	31·3	4·3	5·0	...	7·8	11·6	8·8	10·2	12·0	...	10·9	20·0	15·5	12·8	15·7	7·8	9·0	...	15·5
	March	41·5	35·7	4·2	5·5	...	12·1	11·4	8·4	18·9	18·1	8·6	...	24·1	12·0	15·2	16·2	9·2	9·6	15·6	
	April	51·7	41·8	6·8	2·3	...	12·4	14·9	13·6	20·4	19·9	16·4	...	33·4	22·7	22·1	21·6	16·5	18·0	25·5	
	May	52·9	44·4	5·9	4·4	5·4	8·4	13·2	12·2	16·8	14·5	9·3	...	33·9	27·0	26·5	27·8	20·0	22·2		
	June	58·4	50·5	6·0	3·5	...	10·0	12·2	11·6	13·6	12·9	10·0	...	44·5	35·2	32·0	32·5	...			
	July	61·2	54·3	6·2	4·5	...	12·9	17·3	12·8	14·2	16·8	...	...	47·1	39·3	35·5	37·0	33·8	31·2		
	August	57·7	50·3	6·4	3·7	...	9·5	11·6	10·1	12·6	13·9	...	...	42·8	34·8	31·8	32·8	...	30·8		
	September	57·9	50·2	8·0	4·6	...	13·7	13·1	12·1	...	14·6	...	...	34·8	27·2	25·0	27·5	...	22·6		
	October	49·2	43·5	5·8	4·9	...	13·7	18·8	17·8	...	21·8	...	...	30·8	25·5	24·2	26·2	...	23·5		
	November	44·0	39·6	5·2	6·5	...	9·6	11·0	8·9	...	13·4	...	...	27·4	20·2	19·3	21·8	...	18·0		
	December	33·0	30·4	2·7	7·7	...	13·7	13·5	8·7	...	17·4	...	...	21·1	7·7	7·9	12·4	...	4·0		

The power of radiation, as exhibited in this Table, has evidently no tendency to increase with the heat, and in this respect does not serve even as an approximation to the law of radiation established by the experiments of MM. Dulong and Petit, viz. that the velocity of cooling *in vacuo* (or force of radiation) increases in the terms of a geometrical progression for excess of temperature in arithmetical progression; it is most probable that the effect is masked by too many disturbing causes to enable us from mere inspection to discover the law of its progression.

Table CVIII.—Monthly mean of the minimum temperature of the Air.

Year.	Month.	The monthly mean reading of the minimum self-registering thermometer placed in air at the height of 4 feet, according to the state of the sky.									
		State of the sky.									
		Cloudy.		Broken clouds.		Half-cloudy.		Principally clear.		Cloudless.	
		Number of nights.	Mean of the minimum temperatures.	Number of nights.	Mean of the minimum temperatures.	Number of nights.	Mean of the minimum temperatures.	Number of nights.	Mean of the minimum temperatures.	Number of nights.	Mean of the minimum temperatures.
1843.	April.	2	43°·9	1	37°·4	3	42°·8	2	38°·3	3	40°·5
	May.	12	46·9	6	46·0	4	47·0	7	43·0	2	43·1
	June.	6	51·4	9	49·8	1	47·0	7	48·0	7	47·2
	July.	5	53·3	6	55·2	7	54·1	10	49·7	2	54·2
	August.	2	57·5	2	59·4	7	59·2	12	53·5	6	52·5
	September.	3	58·2	3	54·3	7	55·2	6	48·1	11	50·8
	October.	6	44·9	3	44·4	6	50·0	8	40·4	8	34·6
	November.	9	42·5	2	49·2	7	41·6	7	39·8	6	31·0
	December.	17	40·5	7	42·8	1	40·1	5	37·6	...	.....
1844.	January.	8	33·0	7	37·6	5	34·1	7	34·1	2	22·0
	February.	7	32·3	6	27·9	6	35·3	6	29·4	4	29·4
	March.	8	37·8	5	38·9	9	33·5	2	41·9	7	30·5
	April.	3	47·1	2	46·6	3	45·4	4	43·0	18	39·6
	May.	9	47·1	1	46·2	6	42·4	5	42·5	10	44·1
	June.	2	50·3	10	51·4	7	52·5	5	50·4	6	53·0
	July.	4	56·2	9	55·4	5	54·6	1	53·8	12	52·8
	August.	7	54·8	1	51·6	5	51·1	6	49·3	12	47·7
	September.	6	55·3	5	54·1	2	59·7	5	50·8	12	44·3
	October.	10	47·0	1	45·3	6	45·3	6	46·0	8	40·1
	November.	12	42·6	3	42·0	6	38·9	7	33·5	2	41·6
	December.	23	31·9	...	.....	...	.....	1	30·1	6	24·6

By taking the mean of these numbers according to the number of nights from which each result is deduced, we find that the mean of the lowest readings of the temperature of the air during

161 cloudy nights was	46°·2
89 broken cloudy nights was	46·9
103 half-cloudy nights was	46·0
119 principally clear nights was	43·9
144 cloudless nights was	42·4

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